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ART. XXII.—*Experimental Determination of Wave-Lengths in the Invisible Prismatic Spectrum;* by S. P. LANGLEY. (With Plate V.)

NOTE.—The following investigation was made at the expense of the Bache fund and is published here by the permission of its trustees. It is the subject of a still unpublished memoir presented in April, 1883, to the National Academy of Sciences, in whose Transactions the unabridged communication will be found.

IN September, 1881, while engaged upon Mt. Whitney, in measuring with a linear bolometer the heat in the invisible spectrum of a flint prism, I came upon a hitherto unknown cold band whose deviation indicated a (probably) very great wave-length.* We have had up to the present time no way of measuring such wave-lengths directly, but are accustomed to determine them by more or less trustworthy extra-polation formulæ, the best known of which is Cauchy's. Accordingly, I attempted to calculate the wave-length by Cauchy's formula, but was conducted to an impossible result, the formula declaring that no such index of refraction as I had measured was possible in the prism in question. But the measurement was a fact beyond dispute, and this drew my attention to the grossness of the errors to which the customary formulæ may lead.

Every prism gives a different map of the spectrum, nor when we find a band or line by the prism, have we any means of fixing the absolute place, except by a reference to the normal or wave-length scale, or to one derived from it.

It is desirable to define at the outset, the sense in which the term "Normal" is here used, as a synonym for "Wave-length" spectrum.

The amount of energy in any region of the spectrum, such as that in any color, or between any two specified limits, is a

* Since designated as "Ω."

definite quantity, fixed by facts which are independent of our choice, such as the nature of the radiant body, or the absorption which the ray has undergone. Beyond this, nature has no law which *must* govern us in representing the distribution of the energy, and all maps and charts of it are conventions.

Did the word "Normal," then, signify "absolute," there would be no spectrum exclusively entitled to such a name; but, in this connection, the word is always to be understood in its radical meaning of an accepted rule or type of construction. Such a type exists in the wave-length spectrum; and it has obtained general acceptance, not only on account of its simplicity and convenience, but of its, at present, unique claim to be a "natural" one. It is properly distinguished as the "natural" scale from its not merely representing a mental picture of the distribution of the energy, under a very simple law, but of actually being that which we do produce by our most efficient optical apparatus, and make visible and measurable at will.

While we remain at liberty, then, to represent the energy spectrum in terms of the wave frequency, or of the reciprocal of the square of the wave-length, or of any other function of it, and while we may often find occasion to use these scales for some special purposes, we are (and all the more especially that we habitually speak in terms of the wave-length) led by considerations of a very practical kind, to take as our normal or standard scale, that of the wave-length itself.

Since we have this normal spectrum, actually before us, through the concave gratings constructed by Professor Rowland, it may seem as though we might dispense with the prism; but this is not as yet possible for the lower part of the spectrum, where overlapping spectra and feeble heat make the use of the grating too difficult. If we could use the solar energy here, not in the form of heat, but of chemical action, as in photography, a great advance might be made; and there is reason, I believe, to hope that the labors of Professor Rowland and Captain Abney will ere long do this for us with precision. At present, however, we have only heat, and the thermopile or the bolometer; which latter, though less sensitive than the camera, can be made, as I shall show, to determine experimentally within known limits of error, the actual wave-lengths corresponding to given indices of refraction, and hence to afford here valid experimental data for passing from the prismatic spectrum to the normal one. The reason why this, so desirable information, has never been obtained before, is two-fold: (1st.) While the measurement in question can best be made by means of a prism and grating conjointly, the heat, which in the lower prismatic spectrum is very faint, becomes almost a vanishing quantity when it has passed the grating also, where the

heat is on the average less than one-tenth that from the prism. We must use too, if possible, a narrow aperture to register this heat; for a broad one might (on account of the compression of the infra-red by the prism), cover the whole field in which its work should be to discriminate. (2d.) We must have not only an instrument more sensitive than the common thermopile, but we must devise some way of fixing, with an approximate precision, the point at which we are measuring, when that point is actually invisible.

The apparatus I have devised for this double purpose, has done its work with a degree of accuracy, which if it may be called considerable, as compared with what we have been used to in heat measurements, is yet necessarily inferior to that obtained by the eye, and less than we may hope for at some future time, from photography. Nevertheless, it has, I believe, given experimental data very far outside the visible spectrum, by which we may either construct an empirical formula and supply its proper constants so that it will be trustworthy within extended limits, or test the exactness of such formulæ as Cauchy's, Redtenbacher's, etc., which, while professing a theoretical basis, only agree in their results within the limits of the visible spectrum (from which they have been in fact derived, and where they are comparatively unneeded). They contradict each other, as will be seen, as soon as they are called on for information in the region outside of it, where they would be chiefly useful.

The present work has been preceded by a new map of the invisible prismatic spectrum, where the abscissæ were proportional to the deviations in a certain prism. (See this Journal, vol. xxvi, plate III.) And the immediate object of this research is to pass from the arbitrarily spaced prismatic scale, belonging to the particular prism in question, to a map on the normal and absolutely general one, which was indeed also presented in the same issue, but in advance of the present description of the means used to obtain it.

I should perhaps make the cautionary remark, that the general conclusions here offered, as to the relation of wave-lengths and indices of refraction, have been drawn from the observations on a single prism and have not been experimentally verified on others. This is on account of the extremely slow and laborious character of the process used (which has involved some months of labor for this special prism). Though there seems no reason to doubt the generality of our conclusions, it may be hoped that these experiments will be repeated with prisms of other material, and by other observers, now that the preliminary obstacles have been removed.

In order to map the spectrum on the normal scale, where the

wave-lengths are equally spaced, from such a map as that shown in Plate III (this Journal, vol. xxv), in which the consideration of wave-lengths does not enter, it is necessary to establish some relation between the wave-lengths of rays and their deviations, or between their wave-lengths and refractive indices, which are connected with the deviations by the well-known formula.

$$n = \frac{\sin\frac{(a+d)}{2}}{\sin\frac{a}{2}},$$

where a = the refracting angle of the prism, d = the deviation, and n = the corresponding index of refraction. In the visible spectrum, the deviation, in any prism, of the Fraunhofer lines (whose wave-lengths have been very accurately determined) can be measured by means of an eye-piece with cross wires; and, from a sufficient number of such measurements, by making ordinates proportional to indices of refraction (or deviations) and abscissæ proportional to wave-lengths, a curve may be found whose equation is $n=(\varphi)\lambda$ or $d=(\varphi)\lambda$, representing the required relation to any degree of exactness.

In the invisible spectrum, the difficulties are immensely greater, and demand special means, not only on account of this invisibility, but owing to the absorption by the prism and to its compressing the rays.

The prism here used was made by Adam Hilger, of London, and its optical properties are in every way satisfactory. It is of a white flint, which has proved singularly transparent to the longest solar waves. Its principal constants have been given in this Journal, vol. xxv, p. 187.

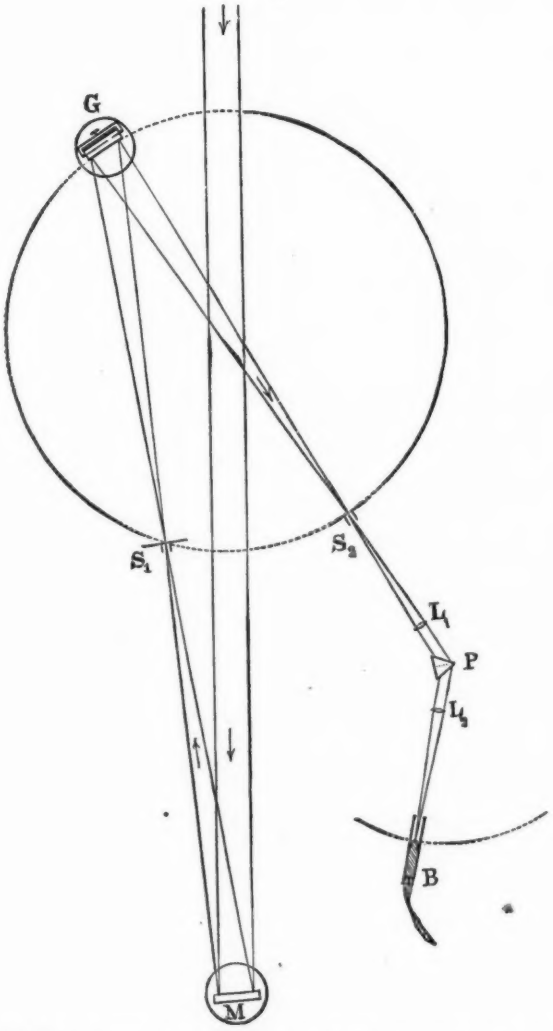
Apparatus for Measuring Obscure Wave-lengths.

In 1882, an apparatus was employed in which invisible rays, after passing through the Hilger prism, at a known deviation, fell on a Rutherfurd reflecting grating (either of 681 lines to the millimeter, or half that number) from which the diffracted invisible ray fell on the bolometer, at a measured angle with the grating. By the use of the known formula ($ns\lambda = \sin i + \sin r$) connecting the angle of diffraction with the wave-length, the wave-length was then found.

Several determinations were thus made of wave-lengths in the upper part of the infra-red, where the heat is relatively great; but, though the definition of the Rutherfurd grating was admirable, it was not large enough to supply sufficient heat to enable measures in the lower infra-red to be made with confidence.

In May, 1882, I had the good fortune to secure one of the very large concave gratings, then newly constructed by Pro-

1.



fessor Rowland, and which he was kind enough to make for me of a very short focus, so as to give a specially hot spectrum. After many essays, during which a great number of mechan-

ical and optical arrangements for getting rid of the superposed spectra, were tried with unsatisfactory results, it became clear that, for this large and concave grating, it was necessary to let the ray fall first on it, and then on the prism, thus making the wave-length the known and the deviation the unknown quantity.

In the use of this form of grating, the slit is placed in the circumference of a circle, whose diameter is equal to the radius of curvature of the grating, and which touches its surface. The spectra are then formed, without the need of collimator, observing telescope or any further apparatus, all lying upon the circumference of the circle which contains the slit. The grating which was employed contains 18,050 lines, 142 to the millimeter, ruled on the surface of a concave mirror of speculum metal of $1^{m}{\cdot}63$ radius of curvature, and exposes a ruled surface of 129^{cm}. By this large surface a spectrum is produced sufficiently hot, even in its lower wave-lengths, to affect the bolometer strips after the various reflections and absorptions to which the heat is necessarily subjected in passing through the apparatus.

Figure 1 illustrates the means finally adopted, and the course of the rays through the apparatus; although, for the sake of distinctness, the mechanical devices used to maintain the proper arrangements of the parts are omitted. The rays of light, coming from the 300^{mm} flat mirror of the large siderostat, pass across the apparatus, and fall upon a concave speculum of 180^{mm} aperture at M, by which at a distance of about $1^{m}{\cdot}5$ they are converged to a focus at S_1. At this point is a vertical slit, adjustable to any desired width by a double screw, which moves both jaws at once, so as to keep the center always in the same place. This slit is protected from the great heat by a plate of iron pierced with an aperture only a little larger than the slit when open to the usual width. Beyond S_1 the rays diverge and fall upon the concave grating, G. Directly opposite the grating is a second slit, S_2, also double acting, and the apparatus is so arranged that the two slits, S_1, S_2, and the grating, G, always lie upon the circumference of a circle whose diameter is $1^{m}{\cdot}63$; and therefore in whatever manner the slits may be placed, the light coming through S_1 forms a sharp spectrum upon S_2. A very massive arm, carrying the grating, the slit S_2, and the heavy spectro-bolometer, is pivoted at the center of the circle, so that the relative positions of these parts are unchanged. The slit S_2 is automatically kept diametrically opposite the grating, and on the normal to its center.

The slit S_2 is the slit of the spectro-bolometer, provided with the same attachments as when used for mapping the visible spectrum (except that it is now fitted with simple collimating and objective lenses of the same special kind of diathermanous

glass as the prism, instead of its own concave mirror.) Its eye-piece and the bolometer are interchangeable.

By means of the eye-piece and graduated circle, the deviation, and consequently the refractive index of the rays passing through the slit can be determined, if they are visible. If they are invisible, their exact wave-length is known by a simple ocular observation of the visible ones, on which they are superposed by the action of the grating, while their subsequent deviation is determinable by the bolometer placed at B, provided they retain sufficient energy to affect the instrument. It will be seen that, according to this method, all those invisible rays, which are n times the definitely known length of some visible ray, are caused to pass together through a slit, and then through a prism, which sorts out the ray of the first spectrum from that of the second; that of the second from that of the third; and so on, so that the corresponding index of refraction may be determined by observation; with the eye in the case of the visible, with the bolometer in that of the invisible ray.

To illustrate the use of the above described apparatus under somewhat unfavorable circumstances, let us consider as an example the observations of June 13, 1882, which were taken far down in the spectrum, where the heat is feeble, and the galvanometer deflection small, requiring a widely open slit. The apparatus having been previously adjusted, and the sunlight properly directed by the siderostat, the visible Fraunhofer line D_1, of the third spectrum of the grating, was caused to fall upon the slit S_2 of the spectro-bolometer. Then, according to the theory of the grating, there passed, through this slit, rays having the wave-lengths—

$0^{\mu}{\cdot}589$ (3d spectrum—*visible.*)
1·178 (2d spectrum—*invisible.*)
1·767 (1st spectrum—*invisible.*)

The prism having been removed, and the telescope brought into line, an image of S_2, of the same size as the slit itself, was formed in the focus of the object lens, and on testing

2.

with the bolometer, whose face was covered with a screen pierced centrally with a 2^{mm} slit, the heat of this image produced a deflection of the galvanometer needle of about 30 divisions. The prism was then replaced on the automatic

holder and set to minimum deviation, and the image of the slit, containing superposed rays whose combined effect had produced the deflection just mentioned was separated into three similar images* (fig. 2) each composed of nearly homogeneous rays. Of these three bands, only the first or most refrangible, containing the D_1 line, was visible, and its deviation was found to be 47° 41′, agreeing with the value given by the table. It was the object of the experiment to find the place of the lower invisible band, by groping for it; *i. e.*, to determine its deviation by trials with the bolometer at intervals sufficiently close to avoid the possibility of missing it altogether. According to Briot's formula, the deviation should be 45° 21′, and in the preliminary search the circle was accordingly set to this reading. Beginning at this point, and exposing the bolometer at every five minutes of deviation, it was found that the maximum effect was obtained nearer 45° 15′. The approximate position having thus been found, the slit S_1 was narrowed to 2^{mm}, and the following measurements taken, the horizontal line giving the mean results of a series of thirty exposures of the bolometer, as it moved through the spectrum.

TABLE I.—*Determination of the refrangibility of feeble heat-rays.*

Prismatic deviation	45° 02′	45° 07′	45° 10′	45° 15′	45° 20′
Means of galvanometer readings	4·6	5·6	6·0	5·8	2·7

The maximum reading at 45° 10′ corresponds to a coincidence of the 2^{mm} bolometer aperture, with the 2^{mm} invisible image of the slit, whose position is sought. From a subsidiary curve drawn through the points whose coördinates are respectively (x=45° 02′, y=4·6), (x=45° 07′, y=5·6), (x=45° 10′, y=6·0), etc., it was concluded that the deviation of rays whose wave-length is 1^{μ}·767 is 45° 10′; and each point in this determination being obtained from the mean of five observations, the result is partly free from irregularities caused by changes in the state of the sky, and minute instrumental variations from extraneous causes, which here become of great relative importance, owing to the feeble heat measured.

Subsequent determinations, like the preceding, gave for the deviation of the same ray 45° 06′ and 45° 07′, and from a consideration of all, the deviation adopted was (instead of 45° 21′, as given by Briot's formula) 45° 08′, corresponding to a refractive index of 1·5549.

* These three images, being composed of rays of different wave-lengths, could not all be in the same focus of the same lens at the same time, since the collimator and objective of this spectrometer were simple lenses. The lenses were adjusted by means of a table of focal distances previously prepared, so as to throw a sharp (invisible) image of the band to be detected.

By means of measurements like the one described above, the deviations of various obscure rays of known wave-lengths were determined. The indices of refraction were then computed by the usual formula $n=\frac{\sin\frac{1}{2}(a+d)}{\sin\frac{1}{2}a}$ where $a=62°\ 34'\ 43''$. The results are contained in the following table, where, however, only the final results of successful days are given, most of the observations having been lost through changes of the sky during the course of one determination.*

TABLE II.—*Experimental determination of* d *or* n *as a function of* λ (*Hilger prism*).

Date of observation.	λ	*d*	*n*
April 1, 1882	$1^{\mu}\cdot010\pm0\cdot0053$	46° 12′	1·5654
April 9th	$1\cdot200\pm0\cdot0069$	45° 54′	1·5625
June 27th	$1\cdot658\pm0\cdot0091$	45° 16′	1·5562
June 13th–27th	$1\cdot767\pm0\cdot0094$	45° 08′	1·5549
July 14th	$2\cdot090+0\cdot0104$	44° 45′	1·5511
June 7th	$2\cdot356\pm0\cdot0110$	44° 25′	1 5478

We observe that where measures are taken in the prismatic spectrum alone, we can generally use with advantage a bolometer of as small an aperture as one-fifth of a millimeter, but that here it is advisable to open it to 2^{mm} owing to the relative expansion of the spectrum and to the very feeble heat.

Owing to difficulties arising from the almost infinitesimal amount of heat in question, numerous subsidiary observations are requisite for a single determination, which it therefore takes long to make, each final value resting upon between 20 and 100 readings. If it should possibly appear to the reader that in the three months of consecutive labor which were given to this part of the work, more than six points might have been determined in the curve, he is asked to remember that what is here difficult has till now been impossible.

Plotting the points given by the data in table II and drawing a smooth curve through them, we obtain the curve of "observation" showing n as a function of λ in the lower curve of Plate V.

There would be no gain in accuracy, at this stage, in attempting to work from a formula representing the equation of the curve obtained, as the graphical construction is fully as trustworthy as the data. This I say with special reference to

* All these observations, for discovering the relation between n and λ, can be conducted with at least as much advantage by a powerful and constant electric light as by sunlight. The latter only, however, was at the observer's actual command.

the large original charts* which have been drawn by Mr. J. E. Keeler, of this observatory, and which seem to me favorable specimens of the accuracy attainable by this method.

We are now prepared to test the accuracy of the various formulæ connecting refraction with wave-length, though it will be convenient to first prepare a table showing what this relation is in the visible part of the spectrum of the prism employed.

In the following table the deviations in the visible spectrum were measured by the spectrometer, reading to 10″ of arc, and which has been already described, in which for this special purpose, the bolometer was replaced by an achromatic observing telescope with a micrometer eye-piece, and the indices of refraction were computed by the usual formula. "O" in the ultra-violet was measured by aid of a Soret fluorescent eye-piece, and its wave-length is from Cornu. The other wave-lengths are taken from Ångström, but the unit is here the micron $= \frac{1}{1000}$ millimeter = (10,000 times the unit of Ångström's scale). "λ" is here the symbol for the wave-length.

The following indices in the visible spectrum, on which the computations for testing the formulæ are founded, are trustworthy to the fourth decimal place here given:

TABLE III.—*Observed indices in visible spectrum of Hilger prism.*

Line.		*d*	*n*
A	$0^{\mu}\cdot76009$	46° 49′ 05″	1·5714
C	0·65618	47° 15′ 45″	1·5757
D_1	0·58890	47° 41′ 15″	1·5798
b_4	0·51667	48° 21′ 05″	1·5862
F	0·48606	48° 44′ 15″	1·5899
H_1	0·39679	50° 34′ 05″	1·6070
O	0·34400	52° 43′ 00″	1·6266

A smooth curve, drawn through points whose positions are given by the above table, represents with accuracy the relation between n and λ in the visible part of the spectrum. This method is however obviously inapplicable to the very extended invisible portion, below the A line, and accordingly attempts were first made to effect the determination of corresponding indices and wave-lengths, by extending the curve derived from the above observations by means of formulæ. Several formulæ have, it will be remembered, been proposed by physicists, expressing n as a function of λ, and containing constants which are to be determined by observation. But it has never hitherto

* These original charts were exhibited to the members of the National Academy of Sciences, at Washington, in April, 1883. The engraving here given in illustration being on a much reduced scale, will merely indicate the exactness of interpolation possible by the originals.

been possible to test these formulæ far from the visible spectrum, whence their constants have been in fact derived. This desirable test we are now prepared to apply.

The simplest as well as the most widely used formula is that of Cauchy, which as it is commonly written

$$\left(n=a+\frac{b}{\lambda^2}+\frac{c}{\lambda^4}\right)$$

contains three unknown quantities, requiring for their determination three simultaneous equations. Selecting the lines A, D and H for this purpose, we have from the table just given the three equations,

$$1{\cdot}5714=a+\frac{b}{(0{\cdot}76009)^2}+\frac{c}{(0{\cdot}76009)^4}$$

$$1{\cdot}5798=a+\frac{b}{(0{\cdot}58890)^2}+\frac{c}{(0{\cdot}58890)^4}$$

$$1{\cdot}6070=a+\frac{b}{(0{\cdot}39679)^2}+\frac{c}{(0{\cdot}39679)^4}$$

from which by elimination

$$a=1{\cdot}5593 \qquad b=0{\cdot}006775 \qquad c=0{\cdot}0001137$$

so that for this prism, the formula becomes,

$$n=1{\cdot}5593+\frac{0{\cdot}006775}{\lambda^2}+\frac{0{\cdot}0001137}{\lambda^4}$$

which we find on trial satisfies the observations in the visible part of the spectrum within very narrow limits. When, however, we attempt to extend the application of the formula to the infra-red region, its results are not so satisfactory. Since b and c are both positive, the least value which n can have in our prism, according to the formula, is a, or 1·5593 corresponding to a deviation of 45° 35′, whereas the bolometric measurements show that in this prism the solar spectrum, after absorption, extends as low as 44°, with every sign that if it do not extend yet further, it is not on account of the prism but because below this point the heat is absorbed by some ingredient of our atmosphere.

We conclude then that Cauchy's formula gives grossly erroneous results, when extended far behind the limits within which the observations on which it is founded are made. Its implicit assertion, that the lower limit of the prismatic spectrum (however great the wave-length of the ray transmitted), is not so far below A as A is below D, is absolutely contradicted by these experiments, and all extra-polations made by it, far from the visible spectrum in which its constants have been deter-

mined, are wholly untrustworthy, as will appear more fully later.

Redtenbacher proposes the formula

$$\frac{1}{n^2}=a+b\lambda^2+\frac{c}{\lambda^2}$$

for expressing the same relation. Using the same lines as before for determining the unknown constants, we have for the Hilger prism

$$\frac{1}{n^2}=0{\cdot}412297-0{\cdot}00093711\lambda^2-\frac{0{\cdot}0039220}{\lambda^2}$$

a formula which also satisfies the observations in the visible spectrum, but fails when extended to the invisible. The curve representing it has a minimum point, corresponding to $n=1{\cdot}5647$ for a value of λ found from the equation $\lambda^4=\frac{c}{b}$ or in the special case of the formula above, where $\frac{c}{b}$ is positive, $\lambda=1{\cdot}430$; so that for every value of n greater than $1{\cdot}5647$, there are two real values of λ. This formula therefore is even less satisfactory than that of Cauchy.

Briot gives a formula which has been asserted by other investigators* to represent satisfactorily the results of observation throughout the whole spectrum, namely:

$$\frac{1}{n^2}=a+b\left(\frac{n^2}{\lambda^2}\right)+c\left(\frac{n^4}{\lambda^4}\right)+k\left(\frac{\lambda^2}{n^2}\right).$$

From four equations like this, using values of n and λ corresponding to the Fraunhofer lines A, C, F and H, the values of the constants were determined† as follows:

$$a=0{\cdot}41028 \quad b=-0{\cdot}0013495 \quad c=-0{\cdot}000003379 \quad k=+0{\cdot}0022329$$

With the aid of these constants, the wave-lengths corresponding to given refractive indices were computed, and a curve representing the formula was plotted. This curve, as well as those representing Cauchy's and Redtenbacher's formulæ, is shown in Plate V where we may obtain by simple inspection the actual errors of all the formulæ in question, or we may take them from the following table, whose results, I hope, will supply useful data for those who are interested in theories of dispersion.

* Mouton, Comptes Rendus, vol. lxxxix, p. 291 and vol. lxxxiii, p. 1190.

† This formula has the practical inconvenience of leading to cubic equations, either in n^2 or λ^2, the solution of which is so tedious as to forbid its use where many places are to be independently found. I have been aided in the present lengthy numerical computations by Professor M. B. Goff.

TABLE IV.—*Approximate errors in wave-lengths by Briot's, Cauchy's and Redtenbacher's formulæ, for cold bands in infra-red.*

(Comparison of theories with observation.)

n By Obs.	Observ'd λ	Wave-lengths derived by extra-polation.							
		From Briot's Formula.		From Cauchy's Formula.		From Redtenbacher's Formula.			
		Value.	Error.	Value.	Error.	Value.	Error.	Value.	Error.
1·5714	0·760	0·760	0·000	0·760	0·000	0·760	0·000		
1·5697	0·815	0·815	0·000	0·818	0·003	0·820	0·005		
1·5687	0·850	0·850	0·000	0·853	0·003	0·862	0·012		
1·5678	0·890	0·891	0·001	0·900	0·010	0·915	0·025	2·230	1·340
1·5674	0·910	0·911	0·001	0·920	0·010	0·941	0·031	2·170	1·260
1·5668	0·940	0·942	0·002	0·960	0·020	0·990	0·050	2·060	1·120
1·5636	1·130	1·170	0·040	1·270	0·140	Imaginary.		Imaginary.	
1·5616	1·270	1·336	0·066	1·730	0·460				
1·5604	1·360	1·450	0·090	2·460	1·100				
1·5576	1·540	1·750	0 210	Impossible.					
1·5572	1·580	1·800	0·220						
1·5544	1·810	2·105	0·295						
to	to	to	to						
1·5535	1·870	2·260	0·390						
1·5520	1·980	2·460	0·480						
1·5515	2·030	2·524	0·494						

NOTE.—A part of the above values of n, where determined from observation by the bolometer, are liable to error in the fourth decimal place. For probable errors of λ, see Table II. "λ observed" is either from a direct observation or from an interpolation between two closely contiguous observations.

It is evident that Briot's formula, though not exact, yet gives results much more trustworthy than the others considered, and it was employed in constructing provisional maps of the normal spectrum from the prismatic, until an apparatus was completed for determining the wave-lengths of the invisible rays by direct measurement.

We must evidently conclude from the numbers in table IV and from the curve in Plate V which embodies them, that we in reality can scarcely assign any limit to the extent of the infra-red prismatic spectrum, and that far from the curve having an asymptote parallel to the axis of X as Cauchy's theory requires, our curve (so far as we can follow it) rather tends to ultimately coincide with a straight line cutting the axis at a finite angle, and (if this axis pass through the point $n=1$) at a great distance from the origin.

With the danger of extra-polations presented to us in such examples as have been cited, we shall not attempt to generalize the results of our observations, further than to remark that, for the prism in question, we find that the deviation tends within the limits of observation to become proportional to the wave-

lengths, as the deviation diminishes, and that, as far as we can see at present, *there is scarcely any limit to the wave-length our prism can transmit except that fixed by its absorptive effect.*

The approximate limit of the solar spectrum of the Hilger prism is at $n=1{\cdot}5435$, which, according to Briot's formula, corresponds nearly to $3^{\mu}{\cdot}4$, but which according to our bolometric observations corresponds to an actual wave-length of $2^{\mu}{\cdot}8$. For this same point, as will be seen by Table IV, the values by Cauchy's formula are impossible, and those by Redtenbacher's formula are imaginary.

These last values rest, it will be remembered, on extrapolations founded on measures in the visible spectrum.

Wave-lengths of Cold Lines in Infra-red Prismatic Spectrum.

The following values (in table V) from Mouton, Abney and Draper are the ones I know previous to my own measures where the wave-lengths of cold lines are given with most accuracy. Of these it is just to distinguish those by Abney as possessing a degree of exactness before unknown. There are some doubts about the band at $1^{\mu}{\cdot}35$ having really been observed before, but I have included this among those whose existence was known or suspected before my measures.

The values here given were obtained by me in 1882, and first published in the Comptes Rendus, of the Institute of France, for September 11, 1882, in the form of charts, which were drawn from them. These charts were so much reduced by the first engraver that though these values are still determinable from them, it may be convenient to repeat them here in their original tabular form, with the addition of the probable errors.

TABLE V.—*Observed values of cold bands in infra-red by different investigators.*

M. MOUTON.*	W. DE W. ABNEY.†	J. W. DRAPER.‡	S. P. LANGLEY.§
	0·824	0·815 0·835	0·815 ±0·003
0·850	0·854		0·85 ±0·003
		0·893 0·930	0·89 ±0·004
	0·905		0·91 ±0·004
	0·941	0·935 0·980	0·94 ±0·004
0·985	0·975 0·983		1·13 ±0·007
1·230	1·240		1·27 ±0·007
1·480	possibly Abney's "ψ"		1·36 ±0·008
			1·37 ±0·008
			1·54 ±0·009 χ
			1·58 ±0·009 ψ
			1·81 ±0·010 Ω
			1·87 ±0·010 Ω
			1·98 ±0·010 ω_1
			2·03 ±0·010 ω_2

* M. Mouton, Comptes Rendus, tome lxxxix, p. 298; tome lxxxviii, p. 1190.
† W. de W. Abney, Phil. Trans. 1880, p. 653.
‡ J. W. Draper, Proc. Am. Acad. 1881, p. 223.
§ S. P. Langley, Comp. Rend., Sept. 11, 1882; Am. Jour. Sci., March, 1883, etc.

Lines known to previous Investigators.

(0·815.) Near the utmost limit of visibility. Appears to coincide with Capt. Abney's Z, and Draper's α.

(0·85.) Apparently agrees with Abney's 8540.

(0·89.) An inconspicuous line. Abney has a heavy line near here. Possibly corresponds to Draper's β.

(0·91.) Inconspicuous; possibly a part of Draper's β.

(0·94.) Very heavy line; marks the extreme limit of Draper's investigations, according to his own statement, and seems to be identifiable with the last definite gap in Lamansky's curve. (Allegheny observations make it probably telluric.)

(1·12.) Still colder than preceding. The gap represented by this line was taken by Lamansky for the end of the spectrum. (Allegheny observations make it probably of telluric origin.)

(1·26.) Inconspicuous line.

(1·35–37.) Very remarkable band. Almost absolutely cold and black. So broad and diffuse that it is difficult to mark its limits, but coldest part seems to have a wave-length of 1·36 and 1·37. (Allegheny observations make it probably of telluric origin.) Possibly the "ψ" of Abney's chart. It seems to be the extremest limit of previous investigations.

Newly-discovered Lines and Cold Bands.

(1·55 and 1·59.) Inconspicuous lines.

(1·81 to 1·87.) Great Cold Band, first discovered on Mount Whitney. Probably of telluric origin. It is not the furthest line, but is here called Ω on account of its being the last *conspicuous* break in the energy curve.

(1·98 and 2·04.) Small but definite lines. The last discovered by the bolometer. But the observable solar spectrum certainly extends to a wave-length of over $2^{m}\cdot70$.

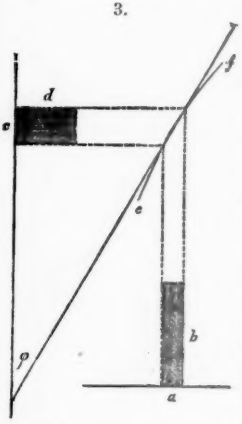
Distribution of Energy in the Normal Spectrum.

The curve $n=\varphi\lambda$ given in the plate enables us to mark off a wave-length scale upon the map of the prismatic spectrum, without any extra-polation, between our present extreme points of observation; a deviation of 50° 58′ (corresponding to $\lambda=0^{\mu}\cdot344$), and a deviation of 44° 25′ (corresponding to $\lambda=2^{\mu}\cdot356$); and also to construct a map in which the wave-length scale is an ordinary scale of equal parts, but in which the degrees of deviation, if represented, would be unequally spaced. Such a chart of the *normal spectrum* has, as we have already remarked, the advantage of being entirely independent of any particular prism or grating, and consequently of being directly comparable with all other maps of the same kind.

If, besides making a map of the normal spectrum, we wish to construct a curve representing the corresponding distribu-

tion of energy, a further consideration of the relations existing between the two charts is necessary. The law of dispersion of the prism causes the distribution of energy in its spectrum to be quite different from what would have been observed with a diffraction grating.* Disregarding the absorbing action of the apparatus, the amount of heat between two definite wave-lengths, as between the A and B lines, should be the same in both spectra, provided the total quantity of heat is the same in both. The area between any two ordinates of the curve† may be considered to represent the amount of heat in the part of the spectrum included between them, and the total area of the curve represents the total amount of heat. If then we suppose the area of the normal curve required to be the same as that of the prismatic one, the condition to be fulfilled by the former curve is, that the area included between the ordinates at any two wave-lengths, shall be equal to that included between the same wave-lengths in the latter, and from this condition we can deduce a construction for effecting the required transformation.‡

3.



* J. W. Draper, Phil. Mag., vol. xliv, p. 104, 1872.

† See this Journal, for March, 1883.

‡ See J. Müller, Pogg. Annalen, vol. cv; Lundquist, Pogg. Annalen, vol. clv, p. 146; Mouton, Comptes Rendus, vol. lxxxix, p. 298.

Lay off upon a line, AB (fig. 4), any convenient distance, and divide it into equal spaces to represent the normal wave-length scale, and upon a line CD, at right angles to the first, lay off the same distance and divide it into the same number of parts, spaced according to the law of dispersion of the prism, as in the wave-length scale marked on the bottom of the prismatic chart (Plate III, this Journal, vol. xxv). Erect ordinates at the points of division, and mark them with the proper wave-lengths, beginning on both lines at the ends which lie nearest to each other, as in the figure, where five ordinates are shown; through the intersection of corresponding ordinates draw the curve EF, and upon CD, draw the curve of distribution of energy in the prismatic spectrum.

Let a, fig. 3, be a very small wave-length interval on the prismatic scale; c, the same interval on the normal scale, and b and d the average heights of the energy curves over the two intervals, respectively; the shaded part of the figure representing, therefore, the portion of the total area included between these limits. ef is a portion of the curve EF, fig. 4. Then, according to the condition of transformation

$$cd = ab$$

whence
$$b : d :: c : a.$$

From geometrical considerations,

$$c : a :: 1 : \tan \phi$$

where ϕ is the angle which the chord EF, joining the intersections of the two pairs of ordinates makes with AB; consequently

$$b : d :: 1 : \tan \phi$$

Such a construction was applied to the prismatic energy curve of the Hilger prism.

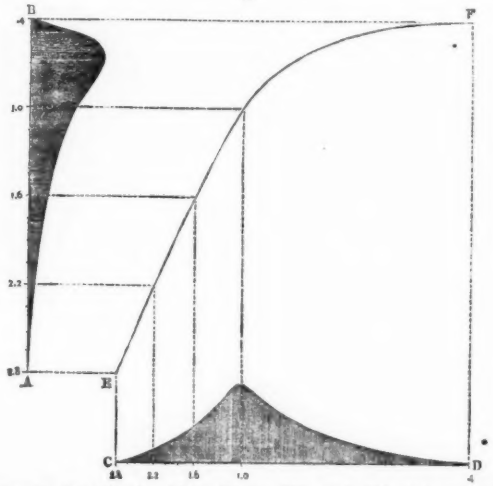
The true normal energy curve with all its inflections, maxima and minima, is easily drawn after this (dotted) bounding curve of normal energy,* is plotted, for the parts of the ordinate of the latter below and above its intersection with the former irregular curve, bear the same proportion to each other as in the prismatic spectrum, and we thus finally attain the object of the preceding labor.

If now it is desirable to map the distribution of the energy on any other scale, such as that on which the abscissæ are proportional to the times of vibration, this can be done with facility. Thus, in the supposed instance, we have only to find $\frac{1}{\lambda}$ for each vibration number to get the abscissæ, and (observing that since y now $=\frac{1}{\lambda}$, $\frac{dy}{d\lambda}=-\frac{1}{\lambda^2}$) to use the multiplying factor $\frac{1}{\lambda^2}$ to obtain the height of the new ordinate in each instance.

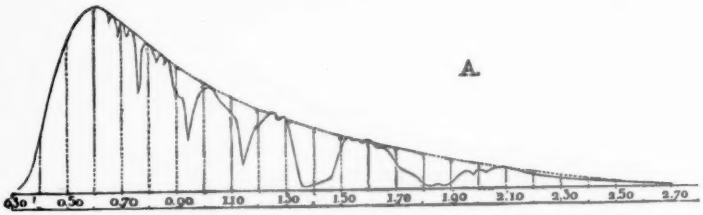
from which $d=b \tan \phi$.

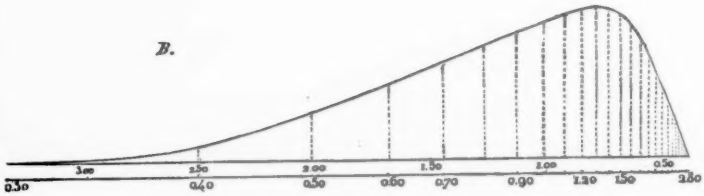
Now, when a and c are indefinitely small, b and d are the ordinates of the prismatic and normal energy curves, respectively, at a given wave-length, and ϕ is the angle formed by the tangent to EF at their point of intersection. Hence, to find the height of the normal curve at a given wave-length, the corresponding ordinate of the prismatic curve must be multiplied by tan ϕ.

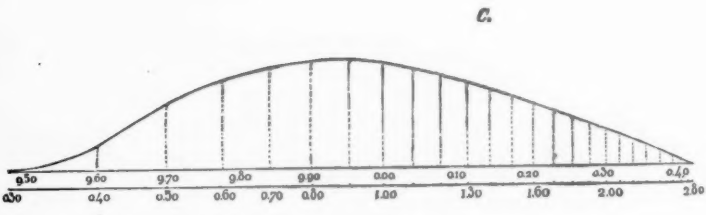
4.

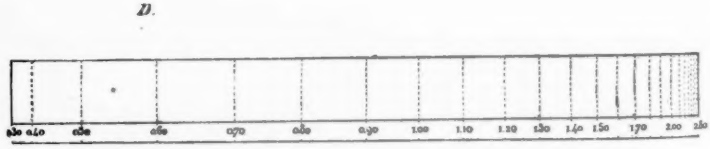


* This Journal, for March, 1883, Plates III and IV (where, however, the maximum ordinate of the normal curve is through an error in the drawing not shown quite in its true position, nearly at $\lambda=0{\cdot}55$).









A. B. Schantz. Del.

If the length of the new energy curve between the limiting perpendiculars (which now represent the reciprocals of the wave-length), is to be the same as in the old, we must introduce a constant multiplier n, writing the equation of the interpolating curve $y=\frac{n}{\lambda}$, so that the multiplying factor becomes $-\frac{n}{\lambda^2}$.

I have drawn in this way (on a smaller scale than that of the normal or prismatic curves and following the smooth curve in the former as my original) four different schemes for the distribution of the energy. Curve A, fig. 5, represents the distribution of solar energy (after absorption by our atmosphere) on the normal scale. Curve B, fig. 5, represents the same distribution on the scale of wave-frequency (general equation of interpolating curve $x=\frac{1}{\lambda}$, proposed by Mr. Stoney.) Curve C, fig. 5, represents the distribution according to a proposal ($x=\log \lambda$) of Lord Rayleigh.

Curve D ($y=$C) is quite different from any of the preceding. It gives the distribution on a scale I have never seen proposed, but which I have found useful. In this, the bounding curve is a *straight line* parallel to the axis of X. This construction is not well suited to exhibit the cold bands, but if we consider only the general distribution of the energy we shall find that curve D is not merely suggestive as illustrating what has already been remarked here as to the conventional character of the methods of showing this distribution, but that it has more practical uses, for in this last construction, it is easily seen that the sums of the energies between any two wave-lengths whatever, are directly proportional to the distance between their ordinates, measured on the axis of X. If then we desire (for instance) to know what relation the invisible bears to the visible heat, or to enquire about what point in the spectrum the energy is equally distributed, these and similar problems are solved through curve D by simple inspection.

I have not been able yet to repeat the preceding determinations upon the lower part of the spectrum as often as I could wish. They are susceptible of improved accuracy by still longer experiment, but I think that within the limits of error indicated they may already be useful. I should add that throughout this investigation I have received constant and valuable aid from Mr. J. E. Keeler, not only in the graphical constructions, but in the experiments and in the computations,

through all the details of which his aid has been more that of a coadjutor, than an assistant.

Allegheny Observatory, Allegheny, Pa., October, 1883.

NOTE.—Since the above was in type I have seen the interesting article by Mr. H. Becquerel in the Annales de Chimie for September, 1883.

The wave-lengths assigned by M. Becquerel to the band at the limit of his researches at $1^{\mu}\cdot460$ to $1^{\mu}\cdot480$ appear to me too great, for this limit corresponds to the diffuse margin of the wide band the wave-length of whose coldest part is given at $1^{\mu}\cdot36$ to $1^{\mu}\cdot37$ on my chart, published in the Comptes Rendus of the previous year (Sept. 11, 1882) and on a larger scale in the American Journal of Science for March, 1883, and in the Annales de Chimie for August of this year. I regret that M. Becquerel has not read the article in the Comptes Rendus. Had he done so he would have seen that the wave-lengths there given were not conjectural, but directly determined by the only practical method from the use of a grating. They were the result, in fact, of the measurements I have just described, and were specially intended to give information about the unknown region extending beyond the limit of M. Becquerel's researches, such as the great newly discovered band Ω, for instance, which stretches from wave-lengths $1^{\mu}\cdot80$ to $1^{\mu}\cdot90$, while M. Becquerel's farthest band as I have said is at $1^{\mu}\cdot48$ (according to him; but according to my measures more nearly at $1^{\mu}\cdot38$). The present memoir will show what degree of reliance may be placed on these measurements.

It is understood that a photographic map of the spectrum to $1^{\mu}\cdot6$, and therefore covering the ground of M. Becquerel's paper, but not extending as far as my Ω, will shortly be published from the joint labors of Professor Rowland and Captain Abney, and as their results from the nature of the method may be expected to be in this respect more exact than the preliminary explorations in which either M. Becquerel or myself have been engaged, we may await its appearance for the determination of a part, at least, of the points in question.

I would call attention to the fact that M. Becquerel has stated that the farthest band known to him in Sept., 1883 (except from my own researches), had a wave-length of not over $1^{\mu}\cdot50$, according to his own estimate.

ART. XXIII.—*The Quaternary Gravels of Northern Delaware and Eastern Maryland;* by FREDERICK D. CHESTER. (With Map.)

THE following paper contains the results of a study of the Quaternary clays and gravels of Northern Delaware and Eastern Maryland, comprising in area the larger portion of New Castle and all of Cecil county, and extending over a period of nearly a year and a half. During the continuous work in the field for the past three months, the northern boundary of the formation or shore line of the Quaternary estuary has been traced for a distance of forty miles, from the northeastern border of Delaware across the State into Maryland, to within a few miles of the Susquehanna, where it curves to the south, running parallel to the river until it reaches the head of the Chesapeake, west of Charleston. All of the area south of this line to a parallel marking the southern border of Cecil county has been systematically studied and is the territory presented for consideration. The entire Delaware and Chesapeake Peninsula is covered with estuary deposits of Quaternary age, and as the present season of field work has been closed, and as the accumulated facts of the whole area would be too great for a single paper, the author has thought it best to divide the whole peninsula into two or three divisions, and to treat each separately, and as fully as the facts deserve.

At the present time we shall therefore discuss what we shall call the northern area.

The history of these deposits forms a part of the history of the flooded Delaware whose record is written upon both sides of the river, as far north as Belvidere, where the much swollen stream entered the region of glacial ice and débris. Although any systematic study of the Delaware flood deposits has been, until lately much neglected, it is certain that whenever the scattered pages of this history shall have been collected, they will form an interesting addition to our present knowledge of glacial and postglacial geology.

General considerations.—South of the region of gneissic and granitic rocks, which are the highlands of both States, all the main topographical features are dependent upon surface formations, the chief among them being of a gently rolling and even morainic character due to the accumulation or irregular distribution of gravel, varying in nature from the finest sand and loam, to pebbles, cobble stones, and bowlders of several tons in weight. Were it not for the preconceived idea of a southern latitude, one might, from a narrow circle of observation imagine himself in the region of the *moraine profonde.* So great is the

physical importance of these morainic gravels that one is immediately led to the study of them in their relation to the Delaware flood history.

Generally speaking, we may say that the whole region is covered with an upper stratum of yellow brick clay, sand, loam or loamy gravel, having an average thickness of about three feet, which is underlaid by a thicker stratum or series of strata of gravel and sand, varying largely in its characters and degrees of coarseness, and having a usual thickness of from 3 to 20 feet. The former homogeneous stratum we shall call, after Professor H. C. Lewis, the Philadelphia Clay, and the latter less homogeneous deposit, after the same author, the Red Gravel. Although the Philadelphia Clay and the Red Gravel are generally distinct deposits, with their well marked characters, such is not always the case, for the two often run into each other indistinctly, the underlying gravel becoming slowly argillaceous as the surface is reached, or again the junction between the two being entirely obscured, or at best but an indistinct wavy line. We therefore regard the two as contemporaneous deposits, with little or no break in the deposition, the one requiring quiet and the other troubled conditions of sedimentation. Considering these facts it seems proper that the two indistinct deposits, i. e., the Philadelphia Clay and the Red Gravel should be included under one head, which we shall hereafter call the *Delaware Gravels.*

The Philadelphia Clay.—The Philadelphia Clay or loam is the universal soil of the entire region, and is an unbroken continuation of the gneissic soil of the hills, distinguished from the latter only by the presence of highly water-worn quartzose pebbles. In lithological characters it varies greatly, but in all cases the sand particles are rounded so thoroughly that the sedimentary and remote origin of the clay is at once obvious. It ranges from a highly plastic brick clay to a loam, even at times becoming a fine white glass sand. It is usually highly micaceous, and although sometimes entirely free from gravel is upon the whole more or less filled with it, together with bowlders varying in weight from five to several hundred pounds. So true is this latter statement that often the deposit assumes the characters of a true bowlder clay, which fact has led other geologists to regard it as the same material transported from the glacier's foot. This is more particularly true of special regions, yet the illustrations might be increased indefinitely. Between Elkton and Chesapeake City, the Philadelphia clay is represented by one thick layer of gravel, cobble stones, and bowlders, cemented by the smallest quantity of a very stiff clay, and rising in high hills with intervening bowl-like depressions. This diluvial stratum which ranges in depth from 5 to

20 feet is found to rest directly upon the Cretaceous with an entire absence of the Red Gravel. Also between Gravelly Hill and Charleston the same features are prominent; the Philadelphia stratum varies from a refractory white clay to a coarse yellow and white gravel, while the surface is literally strewn with cobble stones and bowlders, making the country unusually barren.

Near the neighborhood of Christiana, and from there to New Castle, the clay rises in high hills along the creek, where it is, in places, entirely replaced by bowlders and cobble stones, representing the Potsdam, Millstone Grit, and Trias.

The true brick clay is confined to the low flat lands along the border of the Archæan hills, where the extensive brick yards of Wilmington, Newark and Elkton obtain material for the best variety of brick; but traveling to the south, especially between Kirkwood and the Canal, or to the southwestern limits of the region, the clay changes to a sandy loam or even a yellow and gray sand, which is always mixed with its due proportion of gravel.

The Red Gravel varies still more than the clay in its lithological characters, and consists of coarse red, yellow and gray sands, mixed with very characteristic white oval quartzose pebbles varying in size from a bean to a hen's egg.

From the similarity between widely separated sections, the Red Gravel seems to have a rough arrangement into three distinct strata with quite constant lithological differences. This arrangement is no doubt continuous, although there are local exceptions where only two out of the group of three are represented. In all cases, however, the order of superposition remains the same, while each stratum maintains its own individuality. Beginning with the base of the Philadelphia clay, the following is the order, with the characters of each stratum.

1. Red sand mixed with characteristic oval quartzose pebbles, varying in thickness from 3 to 10 feet. The amount of red argillaceous matter varies greatly, the gravel sometimes being clean, and again when wet forming a very disagreeable mud. It is generally free from, yet again, is entirely filled with fragments of mica and mica schist, becoming a red micaceous sand.

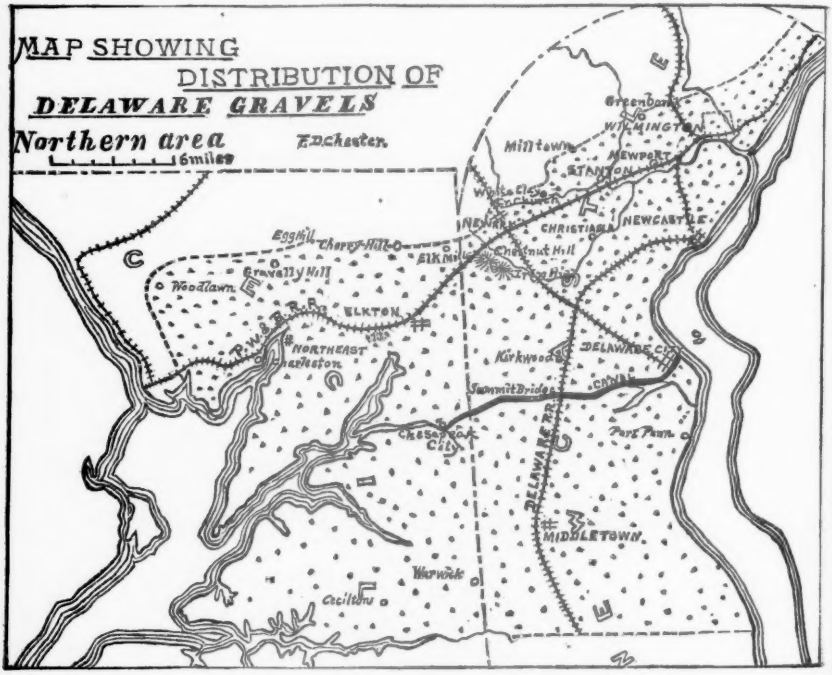
2. Alternate layers of pebbles, with coarse red, yellow, gray and black sand, *entirely free from argillaceous matter*, and showing excellent examples of irregular bedding, particularly oblique lamination, and flow-and-plunge structure. This stratum varies in thickness from 3 to 10 feet.

3. A fine, clean yellow sand showing very delicate examples of oblique lamination with flow-and-plunge structure.

The Red Gravel is abundantly exposed along all the roads

and railroads traversing the region, whenever the talus slopes can be sufficiently removed to give perpendicular cuttings, yet it is only in the deeper gravel pits and cuttings of railroads that the deposit can be sufficiently exposed to give complete results.

It covers the whole region examined, and appears to maintain as great a thickness along the southern line of our present area as to the north, one well near Middletown failing to penetrate the red gravel at a depth of 35 feet.



From the identity of this gravel with the deposits described by Professor H. Carville Lewis* as found along the valley of the Delaware River both north and south of Philadelphia, it is evident that the same is a true river gravel and similar to all the deposits which our present streams lay down over the beds of the estuaries into which they empty.

From the universal coarseness of the gravel, also, together with the abundant evidences of flow-and-plunge structure, more particularly shown along the northern line, it is evident that the same must have been deposited by a swift current, and

*Geology of Philadelphia. Lecture before the Franklin Institute, Jan. 12, 1882.

yet from the vertical heights at which this gravel is found the current must have been deep as well as swift. A glance at the map will show that the northern limit of the Delaware Gravels runs approximately parallel to the river, where the same crosses the northern limits of the State. This river during the latter part or close of the Glacial period was, as we know, a swollen rushing flood, having a width of about ten miles and an average depth of over 200 feet. It emptied into the Delaware Estuary near Wilmington, and its current, urged on with a tremendous head, instead of bending to the south and southeast, as is indicated by the present flow of the river, must have continued in its same southwesterly course entirely across the State into Maryland, until it reached the head of the Chesapeake, where it was stopped by the high hills which rise above the level of the shore line. A belt of gravel thus stretched across the head of the estuary by the current of the river would be subsequently spread out by the waves as a broad sheet to the south.

During the entire time spent in systematic work in the field, the record of every section has been kept; between them all there is great similarity, hence it will only be necessary to give a few of those which show most clearly the range of variation. The new extension of the Baltimore and Ohio Railroad now in process of construction, and extending approximately along the entire length of the shore line has offered most valuable aid, especially as the sections there are freshly cut.

Section on Baltimore and Ohio R.R., Newark, Del.

	Feet.
1. Yellow brick clay, free from gravel	3
2. Red Sand, highly argillaceous, free from gravel	8
3. Rock undecomposed.	

Section in Gravel Pit, Newark, Del.

1. Yellow brick clay, free from gravel	3·5
2. Red micaceous sand, free from argillaceous matter with coarse gravel and sand in lower part	12
3. White fire clay. Cretaceous.	

One mile north of Newark, on Pa. R.R.

1. Yellow brick clay	3·5
2. Red sand, coarse, micaceous with oval quartzose pebbles	3
3. Alternate layers of gravel, with black and brownish sand, irregular bedding with flow-and-plunge structure	3·75
4. Fine yellow clean sand	2·5+

Two miles northeast of Stanton, Del., on Baltimore and Ohio R.R.

	Feet.
1. Loam and sandy clay	4
2. Red, yellow and black sand with alternate layers of pebbles, no argillaceous matter. Very fine examples of flow-and-plunge structure, and other varieties of irregular bedding	20+

Stanton, Del.

1. Yellow clay, sandy and micaceous	4
2. Red sand	14+
3. Alternate layers of clean sand with coarse and fine gravel, with flow-and-plunge structure	

Newport, Del. (gravel pit.)

1. Yellow clay	2
2. Coarse red sand and gravel, compact and highly argillaceous	10
3. Yellow sand, delicate examples of flow-and-plunge structure	2+

Wilmington, Del. (gravel pit), altitude 264 feet.

1. Yellow clay	3
2. Red sand, compact and argillaceous with pebbles	6
3. Alternate layers of yellow and black sand with pebbles, flow-and-plunge structure	10+

Christiana, Del. (gravel pit.)

1. Yellow clay	3
2. Coarse clean sand and gravel irregularly bedded	6+

Delaware City, Del.

1. Yellow clay	2·5
2. Irregular layers of red sand and coarse gravel	4
3. Yellow and gray sand with fine oblique lamination	2+

Section 1·5 miles south of Kirkwood, Del.

1. Yellow, gravelly clay	3·5
2. Coarse red and black sand with gravel	4+

Gravelly Hill, Md., (altitude 388 feet).

1. Yellow clay	2·5
2. Red compact gravel, highly argillaceous (A well near this spot showed a depth of the gravel of 30–40 feet, with fine sand below.)	12+

Middletown, Del.

1. Yellow clay	2·5
2. Red sand and coarse gravel	35+

The Shore line.—After having finished the tracing out of the shore line of the Delaware estuary, which is recorded upon the map, the measurements of the altitudes of the terrace at different points along its line were undertaken. All the heights were taken with a Gay-Lussac barometer, with vernier arrangement for measuring tenths of millimeters, making the usual allowances for temperature. Each measurement was accompanied by a duplicate, and only confirmatory results accepted. By this method much more accurate results were obtained than could be with the use of the aneroid.

All altitudes were calculated from tide water at Delaware City.

	Feet.		Feet.
Back of Wilmington	264	Newark, Del.	100
Green Bank, Del.	269	Elk Mills, Md.	166
Back of Newport	284	Brewster's Mill, Md.	216
Back of Stanton	249	Cherry Hill, Md.	255
Milltown, Del.	269	Back of New Leeds, Md.	360
Pike's Creek, Del.	192	Egg Hill, Md.	370
White Clay Creek Church, Del.	145	Gravelly Hill, Md.	388

From these figures it is seen that the shore line is by no means a level one, and to a person acquainted with the region the reason is obvious. The shore line rests throughout its whole length upon the slopes of the Archæan highlands; these slopes have since the final elevation of the land suffered great disintegration, whereby all definite traces of a terrace have been destroyed, and the author has found it to be generally true that wherever the gravels rose to great height, the underlying rock was hard and durable, and *vice versa*. At Newark the shore line rises only 80 to 100 feet above tide; here the rocks decompose rapidly, while between Stanton and Newport, along the hills, the gravel rises over 200 feet higher, and here the rock, a fine-grained quartzitic gneiss, is extremely durable. Also along the terrace between Gravelly and Egg Hills, the gravel rises to the greatest elevation along the line, while here again the rock, which is a dioritic trap, is even more durable than back of Stanton. We have then to regard the present limits of the gravels as the ragged remnants of what was once a level terrace due to the varying durability of the hills on whose flanks the shore line rested.

That this is true is shown by the finding of cobble stones and even bowlders in places at considerable distances above what is apparently the line of the terrace, mingled with the angular detritus of gneiss. In places in Cecil county, in traveling from the hills into the region of gravel, I have often thought I had reached the shore line by the piles of cobble stones on every

hand, when a few steps beyond would bring me into a region of angular fragments again, while still further beyond, the unbroken expanse of gravel would be reached.

But the best evidence bearing upon this point is to be found near Newark. I have said that there the gravel only rises about 100 feet above tide, where the rock is a very friable mica schist and plagioclase gneiss, both of which are now decaying with great rapidity. Iron Hill, as will be seen by the map, is situated about three miles due south, and here I have found a few of the characteristic quartzose cobble stones within about 30 feet of the summit or at a height of about 225 feet above tide, instead of 100 as is the case at Newark. These facts are enough to convince us that the present shore line is not the original one, which would, in many cases, considering the topography, have to be several miles to the north. Taking the facts as a whole, however, the depth of the estuary waters, or depression of the land, must have been at least 350 feet, which depression would have sufficed to cover the whole peninsula with water, uniting the Delaware with the Chesapeake. This glacial arm of the sea we shall most fittingly call the *Delaware Estuary.*

The floor of the Estuary.—The base of the Delaware gravels, which is both the plastic clay of the Cretaceous, and the upturned edges of the gneiss, has everywhere suffered erosion. The red clay is generally a wavy irregular line, while the gneiss when not decomposed has been well worn. Clearly marked diluvial grooves have in several cases been seen running with the direction of the current, whenever the upper edges of the rocks happened to be freshly exposed, while again the edges have undergone a rough polishing as from the corrasive action of transported sand.

Bowlders.—Besides the Delaware gravels, a most characteristic feature of the region is its bowlders. By this we, more particularly, mean those isolated ones, which cover the surface of the clay, rather than those which form a part of the clay itself, although they are contemporaneous and have the same rock representatives. They are usually quartzose, including the glassy, flinty and quartzitic varieties, and vary in size from several hundred pounds to a ton or more in weight. Great piles of these have been collected from numerous fields. The quartzose varieties, even those of several hundred pounds weight, are all well rounded, evidently by water, and show no glacial scratches. Those made up of coarse constituents are more angular, and in some cases have shown obscure evidences of glacial markings, though as a general thing they show no such signs. Their glacial and iceberg origin is however certain, belonging to those bowlders borne upon the sur-

face rather than ground beneath the glacier's base. The largest ones are scattered over the low ground or Cretaceous plain, yet often those weighing several hundred pounds are found as high as 250 feet above tide. Among the rock species found in bowlder examination, the following are the most prominent:

1. Fine grained red sandstone, certainly Potsdam.
2. Dioritic trap, similar to Triassic bedded trap, (one $3' \times 2\frac{1}{2}' \times 2'$).
3. Yellow friable-sandstone.
4. Hornblende rock in massive bowlders, (one $2' \times 1\frac{1}{4}' \times 1\frac{1}{2}'$.)
5. Black micaceous granite, foreign to the State, (one $2\frac{1}{2}' \times 2' \times 1'$.)
6. Gneiss far to the south, (one $2' \times 1\frac{1}{4}'$).
7. Compact gray limestone.
8. Quartzose, (one $3' \times 2'\ 9'' \times 2'$).

The evident fact that these larger bowlders are of iceberg origin, and their similarity with the smaller ones embedded in the Philadelphia clay, show that this deposit was contemporaneous with the final breaking up of the glacier. Even the unscientific eye cannot fail to be attracted to the great abundance of cobble stones which cover everywhere the surface of the country, and made to see the great part which icebergs play as agents of transportation and deposition.

Bowlders from Iron and Chestnut Hills.—The author has in a former paper (this Journal, Jan., 1883), called attention, under the title of *Bowlder Drift in Delaware*, to two hills lying to the south of Newark. These solitary elevations have for an indefinite time attracted the attention of local scientists, who I believe have been united in their statements as to the cause of their bowlder phenomena, which are thickly strewn over summit and flank. It would be unnecessary again to refer to this interesting case, except that several distinguished geologists unacquainted with all the facts, have been inclined to call the rounded trap rocks bowlders of disintegration, rather than of iceberg origin.

I have first to state, that since the writing of the paper above mentioned, there has been exposed an outcrop of serpentine rock, evidently eruptive, from the fact that the strike of the same is nearly at right angles with the Primary gneiss, following the trend of the hills. How wide this serpentine dike is we are unable to state, but it evidently forms the core or backbone of the elevations.

A glance at the map again will show that these hills lie directly across the current, which by checking its force and producing an eddying would have caused an unusual deposition of the gravel at that point. Icebergs, with their roots reaching deep into the water would further be stranded, and their large bowlders dropped. It is then easy not only to account

for the great thickness of gravel which washes their bases, but also for the enormous rounded bowlders of trap which cover their faces. The height of Iron Hill as stated in the previous paper, and confirmed by a late measurement is 227 feet, or 275 feet above tide. This hill must have then been totally submerged. To those who still think that the trap bowlders are of dike origin, it will be best to present the following arguments:

1. At the northern foot of Iron Hill, there was found an immense pile of rounded and sub-angular bowlders piled on top of each other, like stone dumped from a cart. These were not rolled bowlders, for their size of many tons would preclude all idea of their being thus piled up. With these were associated large quartzose bowlders of undoubted iceberg origin.

2. Bowlders similar to those covering the hills are found to the northeast, and in fact as far off as Christiana and Stanton.

3. Bowlders are found lying upon the ground above the iron ore pits, while no signs of a similar rock are found in the cuttings either fresh or decomposed.

4. The trap bowlders of supposed dike origin are found associated with other rocks of which we have: one bowlder of red orthoclase granite, one bowlder of black micaceous gneiss, one bowlder of limestone, numerous bowlders of decomposed ferruginous quartz, and bowlders of a coarse ferruginous sandeston which have been found scattered quite widely over the area to the northeast. These latter rocks were found in such large quantities upon the hill that they were utilized as trimmings for the Presbyterian church of Newark.

With the main facts of the case thus briefly stated, it seems that there can be left no room for doubt as to the iceberg origin of the trap bowlders even in such isolated positions.

Morainic Phenomena.—We have already referred to the morainic character of the whole region of which we have been treating. These hummocky elevations are cut through by every road, whereby their internal nature is revealed. Sometimes they rise to a height of fifty feet, but have a general elevation of from ten to twenty. They are absent from no part of the region, and with the enclosed bowl-like depressions which separate them, the whole country assumes a rolling character. This is generally due merely to a swelling of both the clay and underlying gravel, but as the clay has but slight thickness compared with the height of the *moraines*, and as this thickness is usually uniform, the swelling becomes mainly confined to the underlying gravel. This gravel deposited in the troubled waters of the glacial and post-glacial estuary, with its strong currents, eddies, and waves, was therefore deposited unevenly over the estuary floor. Taking into further consideration the erosion which the gravel must have suffered during the deposition of

the clay, with the comparatively slight erosion from surface washings and weathering, since the region became land, we can easily account for all the physical features of the surface.

But besides these mere swellings of the surface formations, there are occasionally found coarse gravel hills, which probably were shoal deposits. They rest upon the Philadelphia clay, with their bases ground into it. They are later in age than the latter deposit, belonging to the time when by the final elevation of the land, the waters of the estuary became more shallow and thus more efficient in piling up such shoal deposits. Between Newark and Elkton, a gravel hill rises to a height of 50 feet above the railroad. It is made up of coarse, clean, yellow sand, with pearly white quartzose pebbles. No stratification is visible and the gravel extends downward for the whole 50 feet before the true estuary deposit is reached.

Modern alluvium.—Following the river, from the northern to the southern limits of the region one notices a belt of marsh land upon the Delaware side, beyond which are the gentle swellings of the gravels. This marsh land has been made in very recent times, and consists of black mud, blue clays and river sand of great thickness. A boring made upon the Fort Delaware Island has penetrated through alluvium for a distance of 100 feet.

This alluvial formation has no particular geological interest, except that it indicates a greater width, but not necessarily a greater height of the river than at present.

Resumé.—In conclusion, the following are, in brief, the main events of the Delaware flood history as revealed by the observed facts. Toward the close of the Glacial period, the land of the peninsula became depressed to a distance of at least 350 feet. Into the Delaware estuary thus formed the river of the same name, fed by the melting glacier, poured its swollen rushing flood. Its current, urged by such a tremendous head, pushed its way across the States of Delaware and Maryland, to the head of the Chesapeake. By means of this current and the subsequent distributing action of the waves, the red gravel was deposited.

Later on, the extreme violence of the flood subsided, the land began to rise, and the glacier of the far north to break up. During this quieter period the Philadelphia clay was deposited, while the floating icebergs descending the river dropped over the estuary floor its bowlders. The land continued to rise, until the water became shallow, when the shoal gravels were piled up by the waves and tides, and the elevation still continuing, the river began more and more to assume its present channel, and the waters of the Delaware and Chesapeake were finally parted.

Delaware College, Jan. 1st, 1884.

ART. XXIV.—*On the identity of Scovillite with Rhabdophane;* by GEO. J. BRUSH and SAMUEL L. PENFIELD.

LAST spring we described a hydrous phosphate of the cerium and yttrium earths from Salisbury, Conn., as a new mineral, giving it the name Scovillite.* Our attention has recently been called to the close resemblance of this mineral with rhabdophane, a mineral from Cornwall in England, originally described by W. G. Lettsom,† as essentially a phosphate of didymium and other cerium earths and supposed to be analogous to monazite in composition. A further investigation of rhabdophane by E. Bertrand‡ gave the composition as an *anhydrous* phosphate of cerium and yttrium earths closely related to phosphocerite and cryptolite. A more recent investigation by W. N. Hartley,§ however, proves the mineral to be a *hydrous* phosphate of these earths, of essentially the same composition as scovillite. Professor Hartley's analyses were published in advance of ours and we greatly regret his paper was not seen by us prior to the announcement of our results. Taken in connection with the description of the physical characters given by Lettsom, these analyses leave no doubt as to the essential identity of the two minerals, although there are variations in the relative amount of the constituent isomorphous earths. The American mineral contains no cerium oxide, and has a larger percentage of yttrium earths.

Our mineral contained 3·59 per cent of carbonic acid, which we stated might be considered as due to admixture with lanthanite $R_2(CO_3)_3\ 9H_2O$, or possibly it might be an undescribed carbonate of the composition $R_2(CO_3)_2,\ 3H_2O$. In the former case the remaining scovillite would have the composition $R_2(PO_4)_2H_2O$, in the latter it would be $R_2(PO_4)_2\ 2H_2O$. The English rhabdophane is shown by Hartley to be free from carbonic acid, and the composition is $R_2(PO_4)_2+2H_2O$, consequently we must conclude that the American mineral (scovillite) is associated with a carbonate of the composition $R_2(CO_3)_3,\ 3H_2O$. Assuming this to be true we have present in the analysis we have given 14·11 per cent of this carbonate with 85·72 per cent of $R_2(PO_4)_2\ 2H_2O$. If we may calculate the theoretical composition of this phosphate, assuming the relation of the yttrium to the cerium earths to be 1:4, we have P_2O_5 28·40, $(Y,Er)_2O_3$ 11·12, $(La, Di)_2O_3$ 53·28 H_2O 7·20=100. This is in close cor-

* This Journal, III, xxv, 459, June, 1883.

† Comptes Rendus, April 22, 1878. Communicated to the Academy by M. Lecoq de Boisbaudran.

‡ Bulletin de la Société Minéralogique, iii, 61.

§ Journal of Chemical Society, May, 1882, p. 210.

respondence with the results found by Hartley and ourselves, which calculated for comparison up to 100, are as follows:

	Rhabdophane.*	Scovillite.	Theory.
P_2O_5,	26·26	29·10	28·40
$(Y,E)_2O_3$ }	65·75	9·93	11·12
$(La, Di)_2O_3$ }		53·82	53·28
Fe_2O_3,		·29	
H_2O,	7·99	6·86	7·20
	100·00	100·00	100·00

Of the Cornish mineral it is stated that only four specimens are known, and these are from old collections made in Cornwall prior to 1820. It is a very interesting circumstance that this rare hydrous phosphate should be found in this country, although here also only a few specimens have thus far been obtained.

Art. XXV.—*The Sun Glows;* by Henry A. Hazen.

(Read Feb. 16th, before the Philosophical Society, Washington, D. C.)

The recent brilliant lighting up of the skies after sunset and before sunrise have attracted universal attention, mingled in many instances with not a little superstitious dread. Physicists have taken the matter in hand and have advanced the most diverse hypotheses for an explanation. One of these is that immense volumes of volcanic gas were ejected on Aug. 26, 1883, into the atmosphere from the Straits of Sunda, and that these glows have been due to the diffusion of this gas, and furthermore that this gas has so enveloped the earth as to keep in its summer warmth, so that a mild winter has resulted.

Another theory, which seems to have gained the most adherents of any, is that the volcanic eruption mentioned above filled the air to a great height with ashes and that the upper currents have distributed these ashes over the earth, thus causing an ash canopy, reflection from which results in the glow. This is the theory so ably advocated by Mr. Lockyer in Nature, and more recently by Mr. Upton in Science.

The seemingly unusual nature of the phenomenon, calling for an extraordinary explanation, has induced some to advance the theory that the earth in its orbit has encountered a stream of minute meteors or a cloud of cosmic dust, and that the glow

* Hartley's analysis gave (Ce, La, Di, Yt.)$_2O_3$ 61·69, P_2O_5 24·64, Al_2O_3, Fe_2O_3, CaO, MgO with some P_2O_5 1·93, SiO_2 3·76, combined H_2O 7·50=99·52. The above excludes 5·69 impurities, *loc. cit.*, p. 214. Other analyses are given in the paper, in one of which 23·19 per cent. cerous oxide, and 2·09 yttrium oxide were obtained.

is due to reflection from these particles kept at a great height by electrical repulsion.

It is the purpose of this article to give:

1st. A general idea of the earliest appearances of the phenomenon. 2d. To describe what may be seen by an ordinary observer even to-day. 3d. To present the vapor theory and answer objections. 4th. To show why the "volcanic ashes" and "cosmic dust" hypotheses are untenable.

Remarkable sunset phenomena are reported as occurring on various dates at the following places.

Date.	Place.	Lat.	Long.
1883, Aug. 28.	Mauritius	20° S.	57° E.
30.	Maranham, Brazil	2 S.	44 W.
Sept. 1.	New Ireland	5 S.	152 E.
2.	Venezuela	10 N.	65 W.
5.	Hawaii	20 N.	156 W.
8.	Ceylon	7 N.	80 E.
15.	South Australia	38 S.	143 E.
20.	Cape of Good Hope	35 S.	20 E.
Oct. 8.	Florida	29 N.	82 W.
19.	Yuma, Cal.	33 N.	114 W.
Nov. 9.	England	52 N.	0
20.	Turkey.		
27.	British Columbia, Ala., Cal., Conn., Dak., Fla., Ga., Ills., Ind., Iowa, Kans., Me., Md., Mass., Mich., Mo., Neb., N. H., N. Y., N. C., Pa., Va., Wis., Germany, Italy, Spain, France, Sweden, England.		

Allowing for cloudiness, on certain days, it will be seen that before Sept. 8 a belt of the earth's surface 15° on either side of the equator was suddenly visited by the phenomenon. At first sight it might appear that there was a regular progression from the Indian Ocean westward, but on that supposition it would be hardly possible to explain why Venezuela should have seen the glow six days earlier than Ceylon, though somewhat farther north. The phenomenon might have been seen at Hawaii and even at Ceylon the last of August had it not been for cloudiness; and granting this it is plain that appearances might have been well nigh instantaneous over the regions near the equator. The glow was marked at Yuma on Oct. 19, 20 and 21, after which it ceased for a month. It was first seen in the eastern United States on Oct. 30, when the appearance was very brilliant; the same sight presented itself the next night, but after that it did not again appear as bright, though carefully looked for, until Nov. 27. On this night the spectacle in the southwest was grand and acknowledged by all as the finest even to the present time. The fire engines, at Poughkeepsie, N. Y., and at New Haven, Conn., were summoned to "quench the burning skies." On the succeeding night the scene was nearly the same. Since Nov. 28, the phenomenon has continued more or less brilliant, and with a few complete absences it has appeared down to the present.

A very remarkable fact is to be noted in connection with the display of Nov. 26 and 27, and that is, the sudden brightening over an immense region extending over half of Europe, over nearly the whole of the United States and British Columbia, though it had not been specially noted for about a month previous.

It may be interesting to note a few of the more detailed observations that have been made.

First. Just before and during the glow at night and after it in the morning, grayish, horizontally stratified, light clouds or striæ have appeared above the sun and have extended to right and left. These are invariably present with the glow, though the sky may be otherwise cloudless. On a careful examination, in the evening, these striæ will be usually found passing from a point 20 or 30 degrees to the left of the sun to the right and left and frequently overhead, reminding one forcibly of polar bands which are generally seen in eastern United States (where all these observations have been made) passing from S.W. to N.E.* In the morning in like manner striæ are seen passing above the sun and descending to the NE. or N. and SW. or S. Often the directions of these striæ are confused and marked by cloud layers somewhat nearer the earth.

What are these striæ? On Feb. 1 at 5 P. M. with the sun 10° high the striæ were the plainest yet seen, many of them passing overhead in continuous lines to the NE.

On the right of the sun they were more distinct than on the left, and the radiated structure was very plain, emanating from the N.E. point of the horizon. The next morning the sky was clear, it was even possible to separate ε Lyræ into its components, the striæ were not visible at the first blush of morning, but a careful examination finally revealed them though very faint and of limited extent. On February 2d the appearances were about the same as the previous evening. In the S. a plain cirrus cloud was seen at a great hight, its well-marked streaks dipped to S.E. and W.S.W., appearing as if at the outskirts of a great cloud system gradually advancing from S., though the actual motion of the cloud was from west to east. The streaks of cirrus while prominent did not have a sharp outline and were more or less broken up, while the striæ to the right were sharply defined and unbroken. At 5.30, the sun having set, the cirrus streaks overlapped the striæ and appeared plainly between them and the eye. At 5.35 the glow had begun in the horizon but was at a very low altitude, the striæ being unchanged, while a slight blush just tinged the cirrus

* The term "polar bands" is unfortunate as the striæ are parallel and the seeming polarity is due to perspective. The Germans use "Fallstreifen," and some such word might well be coined in English.

streaks. At 5.38 the former were unchanged, the latter had become a bright red. At 5.43 a slight rosy appearance was noted on the striæ, the color on the cirrus having slightly faded. At 5.44 the striæ were a clear rose color, while the cirrus was only bright near the sun, all color having disappeared from it at 50° to the left. At 5.48 the upper striæ near the sun were bright rose while nearer the horizon there was a deep red color, the cirrus were only seen as dark clouds against the bright red back-ground. The glow was very brilliant and lasted until 6.40. It is plain that the striæ are far above the cirrus clouds and appearances show that they are similar in formation. Whether these striæ are the cause of the glow or not is discussed later on.

Second. During the day with a cloudless sky the sun has appeared as if shining through a dense haze.

Third. On four occasions, January 4, 5, February 2 and 3, the moon was seen shining through seeming water vapor at a great height, the appearance being similar to that frequently noted at other times than the present. There was no halo in these cases, but a distinct ring uniformly bright about 30° in diameter.

Fourth. Several times when there was a plain cloud canopy, though rather light, and through openings in which the blue sky could be seen, the ordinary sunset phenomenon has been seen, upon this canopy, with glowing colors, and one-quarter or one-half hour afterward there has been the wonderful afterglow lasting till the end of twilight.

Fifth. Several times with a clear sky no glow has been seen, though it was quite prominent two or three evenings before and after. This intermittent nature of the phenomenon is regarded as one of its most important phases.

Sixth. The glow has not been quite as deep red in the morning as at night. On the morning of January 27, with a cloudless sky, a grand sight presented itself in the S.E. and E. At 5.50 a red glow first appeared, at 6.10, an intense red had extended to a height of 30°, though a rosy flush was seen even up to 50°, the whole eastern sky was lighted up. The striæ were confused by cloud layers near the observer. This first appearance faded away, but was followed at 6.45 by a still brighter glow. It is probable that this second glow was different from the regular sunrise appearance at 7.13. On February 3, at 6.15 A. M., the sky was very clear and the glow had already begun. At 6.25 the first glow was at its height, it then diminished until 6.35, when there was a very deep scarlet near the horizon. At 6.42 the red again developed rapidly, and at 6.47 the sight was fine, the lower deep red tapering to a rose at 25° altitude, and continuing up to 50°. At 6.55 only a faint

rose color was left. Thus the morning appearances differ from those in the evening, in that they show distinctly this double phenomenon. The two are identical to the observer and the second can be seen even in a perfectly cloudless day.

Seventh. Faint stars and clusters, notably Præsepe, have been easily seen even near the horizon. On January 27, in the morning, while the sky appeared covered by several distinct layers of cloud directly above the sun, yet it was possible to easily find Antares shining through the haze till twenty minutes before sunrise.

Seeking now a probable cause for the glow, it is suggested that at least three conditions are necessary to show the best results.

First. The sky must be clear or nearly so.

Second. There must be an abundance of reflecting, diffracting or absorbing material, as is shown by the well nigh world-wide appearances.

Third. There must be some force to carry the material to a great height or sustain it for a long time against the action of gravity. The lateness of the hour after sunset at which the after-glow disappears indicates that the material may be at a great height, and the fact of the later long continuance of the phenomenon shows that some force must be acting to keep up the particles.

The second condition is abundantly satisfied by the presence of watery vapor, ice crystals or frozen water particles under a peculiar form which is assumed in a rare atmosphere and at a low temperature. It must be admitted that the fact that watery vapor is universally and somewhat uniformly distributed over the earth's surface, and has always been found in great abundance at the extreme limits reached by aeronauts, is a most important one in this discussion. As to the peculiar form of frozen moisture or frost particles at high altitudes, the following experience of the writer may be of interest:

On Dec. 15, 1883, an ascent of Graylock, in Adams, Mass., was undertaken. This peak rises almost abruptly 2,700 feet above a plain which is itself 780 feet above sea level. The summit was reached at 7.30, and here a severe gale, estimated at fifty miles per hour, was experienced. The temperature was 7°·1 below zero and the air was completely saturated with vapor, the wet bulb, after most careful manipulations, reading about half a degree *higher* than the dry. While there seemed to be a grayish cloud overhead, absolutely no ice spiculæ or frost particles could be seen or felt. The sensation was almost a weird one, apparently a dense shadow in broad daylight, with nothing to cast it. That there were minute, invisible, frozen moisture particles, was plain from the beautiful appearance of all trees and shrubs which made it seem as if one had stepped

into an ocean of gigantic coral formations. The frost work was from ·50 to ·75 inch thick upon the branches and trunks of the trees. The frost work after a time formed on the coat of the observer as if accumulated by degrees. These frost particles were too minute to be seen directly, but could easily be recognized either by looking through a great depth or by the effect of the sun's light upon them.

It is not definitely known what causes the ordinary sunrise and sunset colorings, but it is certain that they may occur in all their magnificence in clear skies. The opinion generally held, that they are caused by the absorption of the rays at the blue end of the spectrum by moisture or dust particles, will not explain the present glows. It has been thought, however, that they may be explained if we consider them due to reflection from definite particles in the air. One difficulty in this is that we must assume that reflection and absorption would produce an effect precisely similar to the ordinary phenomenon. It may be said that the ordinary coloring may be caused by reflection, but it is a little singular that such an explanation has not before been suggested by meteorological authorities.

Under the third condition suggested above, some form of electrical action may be mentioned as amply sufficient to fulfill the requirements. We have no means of deciding the height at which frost particles are ordinarily sustained. Siemens has suggested that some form of vapor must be found at and beyond the limits of our atmosphere; however this may be, there must be some cause for so large an increase in the amount of frost particles in the upper regions of the atmosphere as to produce the present remarkable after-glows. That electrical action has been increased of late is evidenced by the behavior of electrical instruments in India immediately after the tremendous convulsion at Krakatoa. Also we note the recent increase in volcanic and earthquake phenomena over the earth, which it is well known is usually accompanied by electrical disturbances. The evidence from the sunspots also points in the same direction. The following table of mean monthly sunspot numbers is taken from "Science" for July 20, 1883. The observations have been made by Prof. D. P. Todd, of Amherst, Mass. I have added the observations since May, 1883, for comparison.

Table of mean sun spot numbers 1880–83.

Month.	No.	Residuals.	3d Order of Means.	Residuals.
1880, January,	11·5	−12·9		
February,	6·4	−18·0	5·8	−18·7
March,	2·1	−22·3	6·4	−18·1
April,	9·1	−15·3	9·8	−14·7
May,	11·7	−12·7	12·5	−12·0
June,	14·8	− 9·6	14·3	−10·2
July,	11·8	−13·6	19·1	− 5·4
August,	23·0	− 1·4	25·3	0·8
September,	33·4	9·0	25·4	0·9
October,	21·4	− 3·0	19·4	− 5·1
November,	15·6	− 8·8	14·8	− 9·7
December,	10·8	−13·6	15·4	− 9·1
1881, January,	18·5	− 5·9	19·8	− 4·7
February,	19·9	− 4·5	26·3	− 1·8
March,	31·9	7·5	30·6	6·1
April,	36·5	12·1	29·6	5·1
May,	20·4	− 4·0	29·4	4·9
June,	34·5	10·1	32·8	8·3
July,	34·4	10·0	33·9	9·4
August,	36·0	11·6	30·1	5·6
September,	25·7	1·3	24·6	0·1
October,	21·5	− 2·9	21·3	− 3·2
November,	19·8	− 4·6	20·1	− 4·4
December,	21·0	− 3·4	20·6	− 3·9
1882, January,	16·6	− 7·8	24·1	− 0·4
February,	32·1	7·7	30·8	6·3
March,	25·6	1·2	40·1	15·6
April,	57·1	32·7	43·4	18·9
May,	40·5	16·1	36·7	12·2
June,	29·3	4·9	28·2	3·7
July,	27·0	2·1	23·2	− 1·3
August,	16·0	− 8·4	23·0	− 1·5
September,	27·1	2·7	25·9	1·4
October,	27·4	3·0	25·7	1·2
November,	28·0	3·6	20·1	− 4·4
December,	12·4	−12·0	15·2	− 9·3
1883, January,	12·2	−12·2	15·4	− 9·1
February,	19·7	− 4·7	19·0	− 5·5
March,	15·0	− 9·4	22·4	− 2·1
April,	35·8	11·4	22·4	− 2·1
May,	7·4	−17·0	26·3	1·8
June,	34·6	10·2	35·2	10·7
July,	48·7	24·3	35·5	11·0
August,	24·0	− ·4	32·0	7·5
September,	31·1	6·7	34·6	10·1
October,	41·4	17·0	37·1	12·6
November,	35·5	11·1		
December,	35·3	10·9		

This table shows an increase of spottedness in April, 1882, when probably the maximum of the present 11 years cycle occurred and after that a marked fall followed since July, 1883, by almost a steady rise. This fluctuation is still more plainly indicated by the residuals in the third order of means. If, as is generally supposed, an increase of solar spots indicates an increase of magnetical and electrical influences, we may con-

clude that the latter have increased within a few months, not manifested however in their usual manner.

Lastly, the arrangement of the "striæ" in the so-called "polar bands," attributed by Professor Loomis to electrical action, also supports the view here presented.

The three conditions, above, enable us to explain all the facts thus far developed. *First:* They must all be existent for the best display. If either of the latter two gradually or suddenly increase or diminish, it would account for the intermittent action. *Second:* Granting the presence of "frost particles" in abundance, the appearances can be easily accounted for, as they are similar to those we recognize when water or frost particles are the cause, whether produced by diffraction or otherwise. *Third:* The transparent nature of the frost particles enables us to see faint stars, which certainly an opaque or semi-opaque envelope would not do. *Fourth:* The detailed descriptions of glows January 27th, February 2d and 3d, show that the striæ or grayish, cloud-like, stratified forms are the true cause of the glows, for if there were other clouds there would have been on the evening of February 3d three distinct appearances: *First*, on the high cirrus; *Second*, on these clouds; and *Third*, on the material causing the after-glow, whereas there were only two distinct appearances. The fact that these are hardly visible in the morning is remarkable and seems to show a change brought about possibly by the effect of the sun's rays impinging, through the day hours, upon the frost particles. *Fifth:* If a progression in many instances be insisted on, and some of the observations plainly indicate this, it is easy to see that the meteorological conditions might bring this about in a movement of the frost particles.

It has been objected that, "The persistence of the phenomenon and its great extent show that it is not due to aqueous vapor." It has been shown, I think, that these very facts are in favor of this theory. A writer in Europe, after noting two specially marked occurrences, and finding that one of them immediately followed a "high" while the other a "low," decided that watery vapor had nothing to do with the glow. It is evident that in order to come to such a conclusion, it must be shown that vapor can be present only in connection with either a "high" or a "low," and does not act with both or independently of either. As a matter of fact most of the more brilliant after-glows have been seen in front of a high area, but this, it is reasonable to suppose, is not due to an intimate connection between the two or the necessity of the presence of the "high" to show the glow, but simply to the clearing of the air in front of the "high," which gives a more favorable opportunity for observation. It is objected that there is a distinct interval

between the ordinary sunset glow upon clouds or vapor comparatively near the earth and the later after-glow, whereas we should expect a continuous phenomenon if the vapor were uniformly distributed in depth. There is no evidence to show that the vapor is uniformly distributed; in fact Professor Vettin, of Berlin, has shown that the clouds have a tendency to arrange themselves in well defined layers at nearly constant heights. "Nature" for December 20th, 1883, gives the following table from his researches:—

Cloud.	Height in feet.
Lower	1600
Cumulus	3800
Cloudlets	7200
Under Cirrus	12800
Upper Cirrus	23000

The suggestion is also made that this indicates a geometrical progression in the heights, with a ratio of two. If such a ratio exists we can see that there might be a long interval between the highest and lower strata.

The most serious objection yet advanced however has been, that the rain-band spectroscope shows an entire absence of watery vapor. This objection is answered by the results of an investigation made by F. W. Cory of England, and recently presented to the London Meteorological Society. He found that a rainband as high as 70 per cent was followed by a *light* rain and one as low as 10 per cent was succeeded by a heavy snow, also that the spectrum is not affected previous to a snow fall except negatively, i. e. the rain-band diminished several days before a snow. He suggests that when vapor is transformed into snow crystals it does not cause a rain-band and that there is no doubt that when rain falls, after a low percentage of rain-band, it is due to either melted snow or hail. The report comes from Magdeburg that in the spectrum of the glow, uncommonly strong rain-bands were seen. This appearance was possibly due to a high temperature, prevailing at the time, which would fill the lower air stratum with water and not frost particles, and hence the spectrum, affected by this stratum, could reveal nothing as to the nature of the substance far beyond. The results of observations with the rain-band spectroscope are now called in question by many prominent meteorologists. In fact the unsatisfactory nature of the evidence may be easily shown to the satisfaction of any one possessing an instrument. If the spectroscope is first turned to the sky in any direction and afterward to a white wall fifty feet distant, it will be found impossible to distinguish between the appearance of the rain-band as shown by the whole atmosphere and by the layer fifty feet thick, and yet we find it insisted upon that the instrument

must be turned to different points in the sky. However this may be it would seem that the presence of an abundance of frost particles would not affect the spectrum as would the same amount of aqueous vapor above a temperature of 32°.

A most singular hypothesis has been advanced to account for the material in the sky, namely, that the volcanic action at Krakatoa on Aug. 26th and 27th ejected, into the atmosphere, immense masses of ashes which have been distributed by air currents over the earth's surface. Vivid accounts of the terrific nature of this convulsion, whereby a mountain island 2000 feet in height was perceptibly lowered, have been published by eye witnesses. The position of the volcano was in lat. 6° 12′ S., long. 105° 28′ E. By comparing this position with the dates and positions of the first appearance of the after-glows as already given, it would seem as though there had been a natural progression, but it has been shown that an instantaneous appearance will account for the phenomena as easily. The following are advanced as a few of the objections to this theory.

1st. There must have been sufficient material ejected to cover more than 135,000,000 square miles (the earth's surface 45° both sides of the equator). The attempt to add to this quantity by instancing isolated and slightly active volcanoes thousands of miles away can be regarded only as an endeavor to support a weak cause.

2d. There must have been currents of nearly equal force acting in *opposite directions* at the same height in the atmosphere, an impossible condition. Meteorology has established that if anything there is a steady current in the upper regions from west to east.

3d. The upper currents must have had sufficient velocity to carry the ashes a distance of 12,000 miles in 150 hours or at a rate of 80 miles per hour toward the *west*. We know little of velocities of air-currents at great heights, but they are probably slight. The summer velocity on Mt. Washington, 6299 feet above sea, is less than 30 miles per hour, while on Pike's Peak, 14,134 feet in height, it is only 20 miles per hour. The conditions certainly are very diverse at the two stations and it is possible that the Mt. Washington velocities are 15 per cent too high, but, allowing for these, there seems to be a possibility of a gradual diminution in wind velocity at increasing heights above the earth's surface.

4th. That the ashes must have been mechanically distributed first along a belt near the equator, and afterward, without addition except possibly of a meager character, the currents must have been sufficiently uniform over the whole earth, to have borne them north and south to above latitude 45°. This is well nigh incredible. It seems probable that in a few

radial lines from Krakatoa, ashes could have been carried 1500 or 2,000 miles, and some sporadic cases even greater distances. Professor Loomis in his Meteorology gives an instance in which volcanic ashes were carried 1200 miles in a single direction, nearly parallel to the equator, but it is more than likely that these were carried in comparatively narrow streams, and that almost the entire mass of matter ejected from a volcano returns to the earth within a few hundred miles. A good illustration of the nature of a stream of volcanic ashes is given by Mr. Whymper, in a recent number of "Nature." He gives a description of a cloud of ashes poured forth from the crater of a volcano, carried in a stream in one direction and afterward in another at right angles, but that there was no uniform distribution is plainly shown by the narrative.

Fifth. That the intermittent nature of the phenomenon precludes the idea of a dust envelope.

Sixth. That ashes are opaque while the appearances indicate great transparency.

The finding of a substance on the windows of a house in Holland, after a great wind and rain storm, which presented a similarity to volcanic ashes, is well known. This evidence must be accepted with caution, however, and it should be shown that it could not have come from the neighborhood, and besides it should all the more be found in other places. Similar substances have fallen at a locality in Spain, but the examiner of them candidly admits that they may have come from the region about.

The theory that the dust has come from space removes many of the objections before mentioned, and seems more satisfactory. The well nigh instantaneous appearance, the last of August and November, gives color to this hypothesis. The other appearances in September and October, at widely separated dates, seem fatal to it however, and besides it is difficult to consider that there were two clouds of dust into which the earth entered.

It is a matter of satisfaction that the phenomenon has attracted so much attention, and called out so many careful observations. These observations should be recorded, and especially any unusual development should be noted. A study of the cloud conditions as a whole, over the earth, will give an additional means of carrying on the discussion. The absence of auroral phenomena and magnetic disturbances at a time of sunspot activity is remarkable. The apparent surprising absence of all unusual appearances on Mount Washington and Pike's Peak demands an explanation. On the former peak a glow was noted December 2d.

While all explanations of the glows are more or less matters of conjecture, yet the field of conjecture is believed to be nar-

rowing, and we may hope ultimately to reach a satisfactory conclusion.

February 3, 1883.

NOTE—February 6th.—"Nature" for January 17, 1884, contains striking corroboration of some of these views. From Honolulu comes a note, that during November the glow somewhat diminished, but since November 25, they have again increased in marked degree. A note from near Warsaw, Russia, gives November 30 as the date of an unusual brightening. Another observer in Freiburg, Baden, reports brilliant red glow, on the morning of January 10th. The morning of January 11th, with a clear sky, the display was confidently expected, but very surprisingly it did not appear at all, the sun rising after a twilight of pale yellow." In the evening clouds arose in the west, at first showing the red marginal coloring of ordinary sunsets, but later on there came again, distinctly higher than even the cirri, a very brilliant and lasting red luminosity.

ART. XXVI.—*Topaz and associated Minerals at Stoneham, Me.;* by GEORGE F. KUNZ.

[Read before the American Association for the Advancement of Science, at Minneapolis, August, 1883.]

THE topaz locality of Stoneham is situated on Harndon Hill, within one quarter of a mile of the Stow line, one and a half miles from Deer Hill, and two miles from the New Hampshire State line and the village of North Chatham. My attention was first drawn to Stoneham, Me., by an exhibition of minerals at the sale of the Mt. Mica Mining Company, September, 1882, where Mr. N. H. Perry had some minerals on exhibition, and for sale. Among these I observed a crystal that I recognized at once as topaz. Mr. Perry, on being informed what it was, instituted further search, resulting in the finding of the finest crystals, and about sixty kilograms of fragments of topaz, with other interesting minerals. A personal visit to the locality and some work there brought the rest to light. To Mr. Perry much credit is due for his keen perception in finding and his care in preserving the mineral specimens.

The minerals to be described in this paper were all found within a radius of fifty square feet in a coarse granite on the summit of Harndon Hill, which is 100 feet wide by about 250 feet long. For a brief mention of the locality, reference may be made to the Proceedings of the New York Academy of Sciences, November and December, 1882, and this Journal, February, 1883.

Topaz.—This locality is the first in New England that has furnished good, clear and distinct crystals of topaz, and thus far it has produced the best crystals found in the United States. Of these crystals, nearly all the finest were found in one pocket in cleavelandite (lamellar albite) at its junction with a vein of margarodite, and one was entirely surrounded by cleavelandite. The finest crystals vary in size from 10^{mm} to the largest which measures transversely 60^{mm} by 65^{mm} and vertically 56^{mm}. They are transparent in parts, and contain cavities of fluids, the nature of which has not yet been determined. A few small perfect gems (see Mining Statistics, 1883, p. 486) have been cut from the fragments of a large crystal that was broken.

The finest crystals are colorless or faintly tinted with green or blue. Some opaque crystals are as much as 300^{mm} across the largest part, and weigh from 10 to 20 kilograms each; they are not perfect in form, the faces are rough, and generally they were broken before they were taken from the rock. The color in these rough crystals is more decided than in the finer ones and is a light shade of either green, yellow or blue. The specific gravity of the transparent material is 3·54, and the hardness the same as that of the yellow topaz from Oura Preto (formerly Villa Rica), Brazil.

The following forms have been observed:

O, *i*-$\breve{1}$; prisms *I*, *i*-$\breve{\frac{3}{2}}$, *i*-$\breve{2}$, *i*-$\breve{3}$, *i*-$\breve{4}$; macrodomes $\frac{2}{3}$-$\breve{1}$, 2-$\breve{1}$; brachydomes 2-$\breve{1}$, 4-$\breve{1}$; pyramids $\frac{1}{3}$, $\frac{1}{2}$, $\frac{2}{3}$, 1, 2; $\frac{4}{3}$-$\breve{2}$, 2-$\breve{2}$.

Many of the crystals exhibit a pearly and at times an opalescent luster when viewed in the direction of the plane *O*, apart from the iridescence produced by fracture and cleavage.

A specimen of this topaz was sent to Professor J. W. Mallet for examination. In a letter to the writer, dated July 27, 1883, he says:

"Mr. C. M. Bradbury, of Petersburg, Va., has made what he himself believes to be a good and accurate analysis, and has obtained the following remarkable results:

Aluminum	27·14
Silicon	14·64
Fluorine	29·21
Oxygen	28·56
	99·55

counting the oxygen as the sum of that equivalent to the aluminum and silicon less one atom of oxygen for two of fluorine found. These figures lead to the usual formula for topaz, Al_2SiO_5, with oxygen partly replaced by fluorine, but presents the remarkable anomaly that, instead of *one-half* of the oxygen

equivalent to silicon being thus replaced, we have *three-fourths* replaced. . . . .

I send you the results for what they are worth. This may be a new and interesting variety of topaz as regards chemical composition, but such a conclusion needs to be confirmed. The specific gravity of the mineral was found =3·54. . . ."

*Triplite.**—This mineral occurs scattered through the rock in masses that weigh from one gram to one kilogram, staining the topaz, quartz, cleavelandite and associated minerals. One mass that may have been a large rough crystal, that was broken to pieces in the blasting, furnished over 50 kilograms of the mineral of a very pure character, in color a light chocolate-brown and clove-brown, and usually with a black coating of oxide of manganese. The interior is streaked with a lighter colored variety of this same mineral that is translucent, but at times transparent in very small fragments. The quartz at its junction with it is often stained black as if the mineral had partly decomposed.

Triphylite.—Only one very imperfect crystal of this mineral was found.

Montmorillonite.—Occurs in masses that vary in color from a very delicate pink to a dark pink closely approximating red, filling the cavities and interstices in the cleavelandite. When the latter is broken, it falls out, and it so far retains the impressions of the spaces it has occupied as to lead one to infer that it has a crystalline form. It also occurs in botryoidal masses resembling rhodocrosite on crystals of cleavelandite. This mineral is evidently identical with that described by Professors Brush and Dana from the Branchville, Conn., locality.†

Columbite is scattered all through the cleavelandite, either on crystals of the latter in cavities, or else between the plates of this mineral. These crystals vary in length from 1 to 10^{mm}, and are not very perfect. In one curious occurrence a number of acicular crystals of this mineral are so bunched together as to have a fibrous appearance, yet each crystal is distinct. One pocket afforded 20 kilograms of pure material, and one mass, or rather a part of a large crystal weighing 8·5 kilograms, appear to have been originally one crystal or one group of crystals. [One very fine brilliant columbite crystal 6^{cm} long was found associated with the herderite.]

Autunite was observed in minute scales on the cleavelandite.

Beryl occurs in large crystals all through the rock, and at times in contact with the larger topaz which it strikingly re-

* Resembling zwieselite of Fuchs. See Dana's System of Mineralogy, 5th ed., p. 544.

† This Journal, III, xx, 283, 1880.

sembles. One vein in quartz with crystals nearly a meter long and one-third of a meter across, was traced for nearly forty feet, without, however, finding any fine crystals.

Zircon occurs in crystals from 1 to 15^{mm} in length scattered through the cleavelandite. The faces are all dull and the crystals are occasionally altered to malacon; those observed were *I*, *i-i* and 1.

Garnet occurs sparingly in poor crystals and is evidently a manganesian variety of the species; it resembles triplite in color.

Cleavelandite occurs by the ton in fine large masses of plates, in color snowy-white, or fading to this color from a dark brown after a short exposure to the sun. Beautiful crystals line the cavities or pockets, in which, as elsewhere, so many interesting minerals are found. The dark brown color is evidently a staining produced by the alteration of the triplite.

Quartz occurs in abundance, usually of a milky color. Masses weighing over 75 kilograms can be easily broken by dropping them, causing them to break asunder as if assisted by some internal force, at which they show an apparent cleavage. The bursting of the fluid cavities with which they are filled may assist the breaking. Some few irregular crystals and some small perfect ones were observed in the cavities. One smoky quartz crystal, or rather group of crystals, measured 80^{mm} by 75^{mm}.

Apatite, in small doubly terminated crystals, occurs in the cavities, often white in the center and blue or green at each end of the pyramid. In one fine group the crystals were white at the center and at the terminations almost sapphire-colored. The plane *O* is largely developed, also *I*, *i*-2 and 1. A massive variety also occurs, compact, vitreous green, the masses weighing 1 kilogram.

Fluorite fills small cavities in the cleavelandite; these masses were rarely over 10^{mm} across, and the color was a very deep purple. A number of very minute octahedrons, resembling blue topaz, were found.

Biotite in slender crystals occurs in the muscovite crystals. Very thin cleavages are dark brown by transmitted light. One crystal was found enclosed in muscovite.

Margarodite occurs here in abundance, of a light yellowish oil-green color. The form of this mineral is nearly radiated.

Muscovite occurs in large masses and hexagonal crystals that are from 2 to 6 inches across, also transparent through the prism, and in masses with a fibrous cleavage, in color brown, yellow and light green.

Damourite.—A curved mica occurs in large shells 4 inches across, saucer-like in shape.

In addition to the topaz and other minerals from Stoneham, Maine, the finding of two beryls, of exceptional beauty for this country, may be mentioned; they were found several miles apart and some distance from the topaz locality. They were discovered by chance, within the last two years, by farmers, in pastures in this township. The first is only one-half of the original crystal and has been roughly used by some one who possibly discarded it as worthless after breaking it, or may have broken it in taking it from the rock. It is 120^{mm} long and 54^{mm} wide, and was evidently at least 190^{mm} long and 75^{mm} wide. The color is a rich sea-green as viewed in the direction of the longer axis, and sea-blue of a very deep tint through the side of the crystal. The color and material in the crystal are the finest that have been found at any American locality, and if not broken, would be equal to the finest foreign specimens known. If cut, it will still furnish the finest colored large gem of this mineral found in the United States, (see United States Geological Mining Statistics, p. 487, 1883), weighing at least 20 carats, and a number of small ones weighing from one to six carats.

The other crystal referred to is doubly terminated, being 41^{mm} long and 15^{mm} in diameter. Over one half of it is transparent with a faint green color; the remainder is milky green and only translucent. At the junction of the two colors in the crystal there is the appearance of a flocculent precipitate, looking as if it had almost completely settled, leaving the upper half perfectly clear. The observed planes are: *O* largely developed, *I*, *i*-2, 1, 2-2, 3-$\frac{3}{2}$. The finding of these two crystals in such a manner can but lead one to think that rich material must be stored in the vicinity and would warrant further search.

[Since the above paper was read the locality has been worked to some extent, and a number of very fine crystals have been found by several parties; among these are several transparent pieces, yielding nearly as fine gems as the ones described, and also some remarkable translucent crystals; one of these measures 910^{mm} long and 110^{mm} in diameter and is of a very fair color. One fragment weighing 660 grams (now in the possession of Mr. Perry) that had originally been entirely transparent but was cracked by weathering, still has a very large clear space, and apparently is a part of the crystal described before. There have been found also some very curious penetrating and enclosed beryls. In one case, a crystal about three inches long and one and one-half inches wide, was penetrated by another crystal, which, as broken out, fits perfectly in the socket. One crystal six inches long had another running through the side, and still another entirely enveloped a smaller one.]

ART. XXVII.—*A Contribution to the Geology of Rhode Island;* by T. NELSON DALE. With a Map—Plate V.

IN a former paper on the Geology of Rhode Island* the writer gave a geological map of the southeast corner of the Island of Aquidneck and of the east shore of the eastern passage of Narraganset Bay from Fogland Point south to Seaconnet Point and West Island, also detailed sections of Easton's Point, the vicinity of Taggart's Ferry, Sachuest Neck, and "Paradise," together with a general section embracing the main features of a belt about two miles wide extending from the protogine bed of West Island to the carbonaceous schists of "The Cliffs" at Newport. The structure of Easton's Point was shown to be that of a simple anticlinal, consisting below of argillaceous schists, containing here and there iron pyrites and earthy chlorite, overlaid by a coarse conglomerate of pebbles of finely stratified, slightly micaceous quartzyte with traces of Lingulæ, possibly of Silurian age. It is uncertain whether the bed of conglomerate at present covers the schist entirely on the line of the section; toward the end of the point it has certainly been entirely eroded. At Taggart's Ferry a sharp anticlinal of this conglomerate is flanked on both sides by carbonaceous schists. At Sachuest Neck a siliceous argillyte, passing into an impure serpentine, and underlaid by a slaty conglomerate with an occasional pebble of red jasper, is conformably overlaid by a highly metamorphic, very coarse, blackish, quartzose sandstone (quartz and clay aggregate) containing in its upper part a few layers of black slate minutely veined with quartz and talc, and containing coal plants, one of which, *Annularia longifolia* Brgt., Lesquereux describes as very common in Pennsylvania, "especially in the lower strata above the Millstone Grit." At "Paradise" seven ridges, from 40 to 173 feet high, trend N.N.E. The two western ones, of quartzyte conglomerate, constitute a synclinal; the two eastern ones, of the same rock, form a ruptured anticlinal. Five beds of hornblende and chlorite schist, alternating with as many of mica schist, constitute the three intervening ridges, forming a monoclinal with a west-northwest dip. This series was probably thrown up in a fault, as suggested by Professor Shaler, although he supposes more faults to exist here than are necessary. The fact that these hornblende and mica schists measure as much as 950 feet in thickness and that they are not covered with the adjoining conglomerate lends some support to the theory that we have here to do with what was an island during the deposition of the

* Proceedings Boston Society of Natural History, vol. xxii, p. 179, Jan. 3, 1883.

conglomerates, and that subsequent flexure of both the hornblende and the abutting conglomerates brought them into their present relations. In the general section referred to, a synclinal and an anticlinal axis were supposed to exist in the chloritic argillytes between the line of West Island and Sachuest Neck, on account of the southeasterly dip of the nearest outcrops of these rocks farther north at Brown's and Church's Points on the Little Compton shore, also because of the W.N.W. dip of the beds at Sachuest Neck. Another synclinal was supposed to occur just east of Taggart's Ferry, and another west of it. Then come the ruptured anticlinal, the faulted hornblende, chlorite and mica schists, and the elevated synclinal of "Paradise;" still farther west is the anticlinal of Easton's Point followed by a gentle undulation, now eroded, along Easton's Beach.

The beds were arranged in the following chronological order: ·01. Granite and protogine; 1. Hornblende, chlorite and mica schist series, 950 feet; 2. Chloritic argillytes and micaceous argillytes, both with minute passages of calcite, 500–750 feet; 3. Slaty conglomerate with red jasper (Conglomerate I) and associated siliceous argillytes and impure serpentine, 500 feet; 4. Quartz and clay aggregate, 750 feet; 5. Argillaceous schists of Easton's Point, 600 feet; 6. Quartzyte conglomerate with a few layers of argillyte (Conglomerate II), 750 feet; 7 and 8. Carbonaceous schists with some conglomerate, associated with argillaceous schists, 1000 feet. (These last are followed by or form part of the Coal-measures proper). Total, 4950–5450 feet. The strata, especially those of Conglomerate II, were found to be fissured more or less vertically and at right angles to the axes of the folds, indicating possibly another system of uplifts with axes running W.N.W.–E.S.E., but less powerful in their effects as would be the case if the strata had been previously corrugated in the opposite direction or had already become rigid by metamorphism. The cleavage of the pebbles of the conglomerate, so often noticed, is probably due, first, to the pressure which made the adhesion of the cement equal to the cohesion of the pebbles, and, second, to the other pressure which fissured, because it could not flexe, the beds. Professor Wolcott Gibbs has suggested to the writer two theories to account for this fissuring: I, *Wave theory:* the conglomerate having been acted upon by a wave motion resulting in a succession of vertical breaks. II, *Contraction theory:* the bed having been heated and beginning to cool at its extremities would be fissured towards the middle by the resulting contraction.

This second paper covers the southwestern part of the island, or Newport Neck and the tract between Easton's Beach, Cod-

dington Cove and the harbor, together with the southern half of Conanicut Island, the west shore of the west passage of Narraganset Bay from Plum Beach south to within 2½ miles of Point Judith, and the smaller islands and rocks between those bodies of land; politically the entire township of Newport and parts of Jamestown and North and South Kingstown. The two papers, together, thus describe a belt across the lands which border and divide the mouth of Narraganset Bay, and afford an entire section across the southern extremity of the New England Carboniferous Basin.

Newport Neck has been pretty fully described* and Jackson's map covers the entire tract. The highly metamorphic character of the rocks of the region, as well as their complex stratigraphical relations, and the fact that half the area is under water must account for the lack of clearness as well as the contradictions in some of the conclusions of the geologists who have studied it. Thus, Dr. Jackson regarded the granite of Newport Neck and Conanicut as intrusive and as having in both places altered the adjoining Carboniferous slates to siliceous and epidotic slates. The central portion of this neck, from Brenton's Cove to Coggeshall's Ledge, he maps as Archæan, the remainder of the neck on the west and a strip on the east, as "Metamorphic Slate," and the entire southern part of Conanicut and the west shore of the bay also as Archæan. Pres. E. Hitchcock also made the siliceous slate of the neck metamorphosed argillyte of Carboniferous age. The part west of a line running south from Brenton's Cove he calls Carboniferous, as he does the dolomite of Fort Adams, and "The Lime Rocks," and the various schists of "The Cliffs." But Professor C. H. Hitchcock regards the granite and protogine of these localities as either metamorphic or eruptive, and in any case as Post-Carboniferous. Older than this protogine but more recent than the Coal-measures he considers the siliceous and other slates of the central and western part of the neck, and also the jasper, serpentine and dolomite associated with them. Above the Coal-measures proper, but below these slates he puts the conglomerate of Coaster's Harbor Island and Miantonomah Hill. Professor Shaler calls the siliceous argillytes of the neck "Primordial Felsites." Professor Hunt is disposed to classify the magnesian rocks of the neck as Huronian and alludes to the granite as intrusive.

* Chas. T. Jackson, Geol. Survey, R. I., 1840, pages 40, 89–92. Ed. Hitchcock, Geol. of Mass., 1841, pages 537, 540, 550, 552. Ch. H. Hitchcock, Geol. of Island of Aquidneck, Proceedings American Association Advancement Science, 1860, pages 119, 121–126, 129–133, 136–7. N. S. Shaler, Geol. of Island of Aquidneck, etc., American Naturalist, vol. vi, 1872, pages 524–5, 616, 619, 752. T. Sterry Hunt. Proceedings Boston Soc. Nat. Hist., vol. xiv, 1869. For full titles and bibliography of R. I. Geology see first paper.

In order to rectify these contradictions and, if possible, determine the structural and chronological relations of these beds the following observations were taken.

Easton's Beach, the Cliffs, Newport City.—At 1 (see map), at east end Easton's Beach, alternating layers of conglomerate and dark gray argillyte dip 5°–10°–20° E.SE.* The nearest outcrop westward is at Bliss' Cave, 2, where similar rocks dip 30° W.N.W. At 3, west end of beach, alternating argillaceous and carbonaceous schists, grits and quartzyte conglomerates measure over 100 feet, dipping 45° W. At 4, corner of Gibbs avenue and Catherine street, 20 feet below the surface, pale greenish argillaceous schists with sparsely disseminated, minute, ferruginous nodules dip roughly W. As "The Cliffs" trend about N. 10° E., nearly with the strike, and as they advance and recede alternately the series is not easily made out.† The layers of conglomerate sometimes run out or fork. Many veins of milky quartz, large and small, traverse the rocks, sometimes starting abruptly from the junction of the conglomerate and slate and tapering upwards through the former, generally vertically and from E.–W. A little N. of 6 the dip is 90° and slickensides occur parallel with strata. At 6 the dip is 60° W. and slickensides are horizontal. At 5 and 6, among the shingle, quartzyte pebbles (possibly not from the outcropping conglomerate) containing *Lingulæ* with plumbaginous shells. The outjutting rocks opposite Narragansett avenue and the like-shaped mass south are due to the converse of the process which formed the chasm "Purgatory," the rock between two E.–W. fissures being left, while that on either side has been eroded. At 7, opposite Miss Wolfe's, about 25 feet of schist overlaid by about the same thickness of conglomerate dip W. At Mr. Lorillard's Breakwater, 8, the easternmost layers, grits and conglomerate, dip 65° E.S.E.; then about 20 feet of grits and dark gray schists dip 45°–50° W.N.W. crossed by slickensides, dipping about 75° W.N.W. Thence to Ochre Point, pale greenish, argillaceous schists with occasional layers of conglomerate, dip 35°–45° E.S.E., measuring perhaps 200 feet. The outlying line of rocks at Ochre Point indicates the direction of the strike and consists of the lowest conglomerate of the Ochre Point series. In passing westward the dip suddenly changes to 25°–30° S.S.W., the rocks being pale greenish, possibly hydro-micaceous schists with minute crystals of magnetite, in places reddish yellow, ochraceous schists, and traversed by several quartz veins. At 9, this bed seems to be underlaid by conglomerate and grit, dipping first 25° E.S.E. then 25°–30°

* These points are all given without allowance for variation.

† Notwithstanding this difficulty Professor Ch. Hitchcock gives a long series of measurements. Op. cit., p. 122–3.

S.S.W. Near 10 the ochraceous schists recur dipping under a large vein mass of milky quartz at 15°–20° S.S.W. South of 10 about 75 feet of finely laminated, carbonaceous slates dip 35°–40° W.N.W. At 11 these dip 45° W.N.W. and continue to Sheep Point and 12, 13. Professor C. H. Hitchcock gives 18 species of coal plants from this bed and two seams of anthracite, 6 inches and 12 inches thick, now probably concealed.* At 12, these schists dip 40° W.N.W. and contain ferruginous nodules several inches thick, minute veins made up of alternating laminæ of quartz and anthracite, and give rise to a ferruginous spring; at 13 they terminate with a high inclination. The next outcrop along shore (about 25 feet off) consists of a soft, decomposed, light gray, argillaceous or talcose schist dipping at high angle westerly, about 45 feet thick, passing into a harder, greenish, talcose schist which passes into a tough, dark gray, slightly purplish, coarsely schistose argillyte with minute veins of serpentine and passages of calcite. This rock forms the headland, 14, and, at 15, passes into an argillaceous serpentine with occasional layers of chloritic talcose schist, nodules and veins of epidote, passages of chlorite and both large and minute veins of quartz, dipping about N.N.W. The islet and rocks to the east seem to be of the same character, thus bringing the easternmost exposure of this bed on a line with Ochre Point. On the south it continues to 16, where it is in close contact with protogine, hand specimens showing both rocks together. This protogine forms the whole point and Coggeshall's Ledge, in places is characterized by large crystals of feldspar, according to Professor E. Hitchcock by faulted veins,† at one locality is traversed by a vein ? of yellowish serpentine, and at 17 near Bailey's Beach underlies the epidotic and chloritic schists again. These may be traced to 18 and 19. The contact occurs in this wise at 17: Lying immediately upon the protogine are layers of ferruginous chlorite dipping N. at a high angle, followed by layers of quartzyte with quartz pebbles and pyrites, measuring altogether about 17 feet, and followed by about 13 feet of protogine with large crystals of feldspar, upon which rest the epidotic and chloritic schists. North of Bailey's Beach the first outcrop is at 20, on the east side of Almy's Pond, where clay slates, like those associated with the conglomerate of "The Cliffs," dip 55° N.W., recurring at 21 and again at 22 near the corner of Spring and Perry sts. In digging for a sewer the rocks were recently exposed for the whole length of Levin street, pt. 23. They are gray argillaceous and perhaps micaceous schists, with thickly disseminated minute grains of a ferruginous mineral, and dipping about 25° W. Similarly speckled schists occur at 1, 2, 22, and were ex-

* Op. cit., p. 125. † Op. cit., p. 693.

posed on Bellevue avenue from Levin to Pelham streets. At 24, near corner of Clark and Mary streets, a 2-foot seam of coal was struck. At 25, near corner of Farewell and Marlborough streets some black slates were exposed several years ago with *Pecopteris arborescens* and *P. hemitaloides*, together with a new species which Lesquereux named *P. Clarkii**; at 26, Fort Greene, and the adjoining "Blue Rocks" dark gray argillaceous schists dip 30° N.W.

Miantonomah Hill, Coddington Cove.—At 27, in a ravine south of this hill, is an outcrop of more than 20 feet of light gray argillaceous schists associated with a conglomerate of small quartzyte pebbles dipping 20° N. At 28, west of the hill, quartzyte conglomerate and argillyte dip 40°–45° E. to N.E. The summit of the hill consists of a coarse conglomerate, like that of Easton's Point, 10–15 feet thick, overlying a siliceous, argillaceous grit, all dipping 15° S.E. to S.S.E.† These grits crop out again at 29. Schists, like those of 27, but of uncertain dip, are exposed by the railroad cutting at 30. At 31, Coddington Point earth works, dark gray argillytes dip 10°–15° S.W. At 32, the most easterly outcrop on Coddington Cove, is a 40 feet high cliff of more or less carbonaceous schists, slates and sandstones dipping 15°–20° S.W. At 33, the dip changes to 25°–30° W., a little north to 30°–35° N.W., the bend in the shore being just opposite to that in the strike. Some of the schist near 33 resembles that of Levin street, etc. Beyond, the strata strike N.–S. with a very high westerly dip and so continue to 34. At 35, 20°–25° W., and a little south the remains of a thick vertical quartz vein stand on the beach associated with the regular conglomerate but both vein and rock contain much chlorite.

Bishop Rock.—On the east side, argillaceous and carbonaceous schists, alternating with grit and quartzyte conglomerate, dip 30°–35° N. to N.N.W. The carbonaceous schists with ferruginous nodules on the W. and N. side dip 45°–50° N.

Coaster's Harbor Island and Rock, Gull Rocks.—At 36 slaty, chloritic argillyte with small passages of calcite, a rock similar to that at Brown's Point in Little Compton, dipping 25°–30° N.E. At Coaster's Harbor Rock, which lies due S., the same rock recurs, dipping 15° N., and also at the Gull Rocks, dipping 15°–20° N. with E.–W. vertical fissures. In the little

* See II Geol. Survey Pa., vol. P, text p. 261 and plate.

† Two bowlders from this vicinity are of extra-limital stratigraphical interest. One, found by Mr. Alexander Peckham SW. of 27, a reddish crinoid limestone with a Spirifer and Strophomena. The other, from the east base of Miantonomah Hill, a dark gray argillaceous schist with minute crystals of Ottrelite (Newportite) and an impression of a plant stem 14 inches long and 1 inch wide marked with longitudinal grooves 1½mm. apart. Bowlders and pebbles of Ottrelite schist abound about Newport, but I have failed to find any outcrop of it.

cove N.W. of 36, gray argillaceous schists, with minute nodules of some talcose mineral and ferruginous veinlets, dip 20°–25° N.E., reappearing on the W. side at 37, with a dip of 25°–30° N.E. The projection S. of 37 is "quartz and clay aggregate" like that of Sachuest Neck, with some carbonaceous slate. At 38, the conglomerate and associated beds commence, dipping a little farther north 35°–40° E.S.E. with N.N.W. fissures. The peculiar looseness of this conglomerate has been described by Prof. Ch. Hitchcock.* The pebbles increase in size northward, the largest about 8 × 10 inches; they are rather spherical, mainly quartzyte but sometimes argillyte. At 38, it contains pieces of carbonaceous slate and of the speckled slate of 36, 37. Near 39 a piece over 6 inches wide of alternating laminæ of anthracite and quartz, like the small veins near Sheep Point. This may have been a fragment from a seam of impure coal or, as seems quite as probable, from its adhesion to the rock, may have been formed at the time of the deposition of the conglomerate. This conglomerate occupies the remainder of the island, on the west side with schist and grit, at 39, dipping 25°–30° about S.S.E.; at 40, 30°–35′ E.S.E., on the northeast side, N.N.W. at high angle, and at 41 and 42, with carbonaceous, speckled slate, 20°–25° N.N.W.

Goat Island.—A boring recently made within the fort, after passing through 50 feet of alluvial gravel and clay, entered the chloritic argillytes with passages of calcite for about 150 feet.

Little Lime Rock (misleading in name).—Chloritic argillyte striking N.N.E.–S.S.W. and dipping almost vertically. At 43, and thence southward to the shore, these rocks recur, dip 15°–20° SE.

The Lime Rocks.—The western one is a light gray, inclining to bluish, dolomite, traversed by veinlets of quartz. A microscopic section shows nothing but the structure characteristic of limestones. On the south side are a series of joints or layers with a rough easterly dip. This grayish dolomite forms also the western half of the eastern rock, its other half being a yellowish, pinkish dolomite of the same character but containing dark purple and rarely green, slates. In one spot layers of purple slate alternate with 2-inch layers of dolomite; the dip uncertain. The small protruding rock south of these is dolomite but possibly a bowlder.

Newport Neck.—The line from 44 south to the west side of Bailey's Beach forms the eastern boundary of a bed of protogine. No contacts between it and the argillaceous and carbonaceous schists on the east have been found. From 44 west to 45, and thence north to near 47, the limit of the protogine is concealed and as the nearest outcrops north are at the Little Lime

*p. 130.

Rock and 22, there is about half a mile square here of uncertain age. At 47 and 48, the protogine is bordered by a narrow strip of highly inclined, siliceous argillyte; at 51, these rocks are seen in contact. The protogine becomes a compound of greenish feldspar and hyaline quartz, and the overlying rock is a stratified flint. From 51 to 50 there is a low cliff probably due to a fissure. From 57 to 58, the two rocks are again in contact and at 52 and 54 small insulated masses of siliceous argillyte overlie the protogine. At 46, distinct strata dip 40°–50° W.N.W. crossed by vertical fissures running E.S.E.–W. N.W.; and, at 53, this stratification is crossed by a system of joints dipping E.SE. At 49 are large veins of massive, bright pink feldspar and milky quartz. At 56, on Lily Pond Beach, the protogine is traversed by veins of flesh-colored, cryptocrystalline feldspar and quartz. The southernmost exposure is at Gooseberry Island. Lithologically, the rock varies from a compound of quartz and pinkish feldspar, or of these with chlorite, to one of all these with a greenish feldspar; and in a few places it is probably a true granite. Its area measures $1\frac{3}{8}\times\frac{7}{8}$ of a mile.

To the west of this tract is the "Flinty Slate" about $1\frac{7}{8}\times\frac{7}{8}$ of a mile in extent. The contact on the north, south and west is concealed or obscured by sea, marsh or beach. At 59, near the protogine, the dip is 50°–55° W.N.W.; at 60, 35°–40° W.N.W.; at 61, about the center, 35–40° N.W. From 62, on the south, northward to 63, the dips are: 62° N. 12° W. 70°, 65°–70°, 55°, 50°, all N.; a little west of 63, 35° E.S.E., a little north of it, 65° E.; on the south side of Price's Neck, at 66, 10°–15° E.N.E. In the northern part the dip is high and uncertain, but the strike in several places is clearly N.E.–S.W. The rock is a siliceous argillyte; in some places an impure serpentine, slaty or massive, varying in structure from finely granular to impalpable; at one locality it is an agglomeration of very small pebbles. The color is generally dark gray, sometimes with a greenish tinge owing to minute veins of serpentine. The point forming the east side of Brenton's Cove is a massive, dark purple, siliceous argillyte, with veinlets of pale green serpentine, enclosing, at one spot, amorphous calcite, and at 65, a bed of greenish gray talc several feet thick, which seems to recur at 64, where it is dark green and associated with asbestos and picrolite. Seams of serpentine are not infrequent in that vicinity and the schist is somewhat plicated, but the old locality of precious serpentine is now concealed.* Both on the north and south sides of the tract thin seams of black, siliceous argillyte occur. A little west of 63 the rock is very argil-

* A compass box made of this serpentine was so magnetic as to render the compass useless.

laceous and schistose; also at 62, 70 and 66. At 62 and 70, this appears to be exceptional, for on Price's Neck it is again more siliceous. At 66, it encloses fragments of chloritic argillyte. The adjoining rocks on the west are not dissimilar and dip 15°–20 N.E., as do the slates a little north, which belong to the siliceous argillytes. It is difficult to determine the precise boundary at this point. Perhaps it should be drawn at 67 where greenish-gray slates dip 10°–15°–20° E.S.E., and hold nodules of a decomposed ferruginous quartz.

The rest of the neck is mainly occupied by bluish green and dark purple, slaty, chloritic argillyte. At 71, it is decidedly chloritic, dipping 35° N. 12° W., containing passages of calcite, and underlaid by a ferruginous, siliceous chlorite schist,* resembling somewhat that at 17, Bailey's Beach, but, still more, certain layers in Church's Cove, Little Compton, at the base of the chloritic argillytes. Some disturbance has occurred here, for these ferruginous rocks protrude through the overlying argillytes and a thick quartz vein with chlorite traverses close by. At 72, these argillytes with calcite dip 15° N.E., at 73, 10°–25° N.E., at 74, alternating with dark purple ones, 10° N.E. A little west the purple and green run in stripes across the bedding and the layers seem somewhat talcose. At 75, Graves Point, veins of quartz with chlorite; a little west, Black Point, the dip is 10°–15° N.E., at 76, 10°–15° E.S.E. At 77, green and purple, very finely laminated and lustrous slates dip 15°–20°–25° N.N.W.; at 78, the purple ones, 5°–10° N.N.W. abounding in calcite. A little north the dip is 15°–20°–25 N.N.W. At Ragged Point, grits and purple slates, 15°–20° N.E., at 80, Ram's Head, 15°–25° N.E. with quartz veins containing chlorite and feldspar, and slickenside planes 25°–30° S.S.E. At 81 the slates dip 10°–20° E.S.E. On the west side of Castle Hill the argillytes abound in calcite. At 82 purple and green slates dip 25°–30° E.S.E. A recent excavation south of 82, brought to light green argillyte containing large nodules of limestone traversed by small veins of crystalline calcite. At 83, the dip is 35°–40° N.N.W., at 84, purple and green slates with calcite, dip 15°–20° E.S.E. From 84 to 85, grayish, greenish and purplish schists, here and there with calcite, dip 15°–35°–50° E.S.E. At 85, on Point of Frees Beach, plicated schists of alternating laminæ of quartz and slate crop out, dipping 20°–25° E.S.E. At 86, the chloritic argillytes dip E.S.E. and at 87, with calcite and pyrites, 10° E.S.E. From 87 southwest to 73, there are a number of outcrops. At 88, purple slates dip 30°–35° E.S.E.; at 89, purple and green, the former enclosing dark purple jasper, dip E.S.E., and continue in a ridge trending N.N.E. The small bowlders and pebbles of dark purple

* See Ch. H. Hitchcock, op. cit. p 126.

and red jasper on the beaches about Brenton's Point, probably originated here. At 90, which is 200 feet from the "Flinty Slate," the dip is 25°–30° E.S.E. The two protruding rocks in the northern part of the marsh dip toward the Flinty Slate in a general E.S.E. direction. At 91, near the artillery stables, the green slates dip 15°–20° E.S.E., and a lenticular mass of quartzyte, 15 feet thick by 40 feet long, is partly enclosed by them. Quartz veins abound hereabout. Returning to the west shore of the neck: from 85 to 92 there are dark purple schists passing into dark greenish ones, dipping 20°–25° E.S.E., and at 93, north of the redoubt, overlaid by the bluish green schists with a similar dip. At 94, opposite the harbor, are exposed at low tide green and purple slates containing nodules and pebbles of dolomite and red jasper, alternating with layers of a pinkish, yellowish, dolomite with veinlets of quartz like the dolomite in the eastern "Lime Rock" and enclosing pieces of slate. A microscopic section of it shows nothing but the structure characteristic of limestone. These beds strike N.E., and the dip, not clear now, Prof. C. H. Hitchcock found to be 40° S.E. Fragments of a bluish gray dolomite, like that of the western "Lime Rock," lie on the beach at 95, probably originating in the outcrop mentioned by him but now concealed.*

Rose Island.—The wider southern portion is entirely chloritic argillyte, dipping on the east and south sides 20°–25° N.E., on the west, 10°–20° N., and a little east of the lighthouse, traversed by veins of quartz, chlorite and feldspar, identical with those at point 80, Ram's Head. At 55, about 1000 feet from the northern end, these rocks are followed by the "quartz and clay aggregate" of Sachuest Neck, etc., dipping 35°–40° E., and followed at the end itself by carbonaceous argillytes with the same dip.

Conanicut.—The two parts of this island are united by the narrow strip of beach forming the head of Mackerel Cove. The northern part ends south in a hilly tract of protogine about $1 \times \frac{1}{2}$ mile in area generally consisting of a pinkish and a greenish feldspar, quartz and chlorite At 101, this is traversed by one large and several small veins of milky quartz striking N.W.–S.E. and dipping N.E. Near 100, the pink feldspar occurs in large crystals, and at 100 the protogine is seen in contact with a siliceous argillyte, the two rocks being literally dovetailed into each other. This is due to faulting as may be seen from a four-foot long vein close by, which is faulted ten times. This siliceous argillyte passes shortly into a serpentine and epidote schist containing nodules of crystallized epidote and some quartz pebbles, resembling generally the schist at 15, at the end of "The

* Op. cit. p. 131; see also Jackson, pp. 34, 91, 246, and Ed. Hitchcock, pp. 537, 552.

Cliffs" in Newport. The dip is about easterly. There is a vein one foot thick of pink feldspar and quartz like those of 56, Lily Pond Beach. Near 99, this rock passes into a chlorite schist with a little mica and minute passages of calcite, and is identical with that of a portion of Ridge III, "Paradise." The "Dumpling" Islets seem to be of the same character, but the one S.E. of 100 is protogine. At 99, the chloritic and epidotic schists terminate. From 98 to 97 the protogine is bounded by the regular siliceous argillytes, like those at Newport and Sachuest Necks, which extend to 102, within half a mile of Jamestown Ferry; at the east end of Hamilton avenue, dipping 15°–20° E.; at 103, more highly inclined and striking N.N.W.–S.S.E. From 97 to 96 the protogine is bounded by a triangular mass of "quartz and clay aggregate," the last outcrop of which is at 104. At 96, on Mackerel Cove, these two rocks are seen in contact. The quartz of the protogine is dark colored, like that of the "aggregate" which lies upon it and which contains a few layers of dark gray slate. The dip is high and hardly determinable, but at 105, dark gray slates dip 10°–15° N.W., overlaid beyond, along the shore of the cove, by light colored, finely laminated, argillaceous slate dipping successively 20°–30° W.N.W., 30° N.N.W., 15°–20° N.N.W., and frequently striped across the bedding, enclosing siliceous-ferruginous matter like the slates at the southwest corner of Coasters' Harbor Island. North of Mackerel Cove, from 106 to 108, similar light and dark gray schists and slates recur, dipping successively 20°–25°, 45°, 25° and 30° W.N.W., with thickly disseminated, minute nodules of crystalline siderite, in some places striped across the bedding, and traversed by quartz veins with crystalline calcite which, from its color in weathering, must contain some carbonate of iron. No satisfactory outcrops exist east of the line just followed, but on the east side of the island at 102, beyond the northern termination of the siliceous argillytes, the argillaceous slates of the east side of Mackerel Cove recur, dipping at 107, 10° W., a little south of the ferry, 25° S.S.E., at the ferry W.S.W., and at Taylor's Point, 10°–20° S.W. to S.S.W.

The southern part of Conanicut consists entirely of the siderític, argillaceous schists described, although in some places the siderite is wanting. The overlying rocks occur at Beaver Head. At 109, south of the Mackerel Cove beach, the schists dip 15° N.W., at 110, north of that beach, 25°–30° N.W.; at 111 they are dark colored as at 108; at 112 they dip 35°–40° N.N.W., becoming north somewhat ochraceous; and at 113 similar schists dip 40° S.S.E. to 90°. Between 113 and 114 there are no outcrops; but at 114 dark mica schists dip E. S.E. at high angle, and a little beyond stand erect, striking with the east shore of Dutch Island, much plicated, in folds several

inches across, and veined with quartz. At 115 these mica schists are interstratified with conglomerate of flat pebbles of quartzyte, micaceous and argillaceous schist, dipping 20°–25° E.S.E. At 116 carbonaceous and argillaceous schists dip 45° E. S.E. The siderite schists on the west shore of Mackerel Cove, from 109 south to 120, dip successively, 15° E.S.E., 15° N.N.E., 10° N.E., 20°–25° N.E., 30° N.E., 25°–30° N.N.E., 20° N.N.E., 25°–30° E. by S.E., 15° E.N.E., 10° N.N.E.; at 121 in Hull's Cove, 15° N.N.E.; from the west side of Hull's Cove to Beaver Tail Light, successively; 10°, 30° N.N.W., 5° S.S.E., 5°–10° N. N.W., 10°–15° W.S.W., 10°–15 N.N.W., 15° N.N.W., 5 N.W. or N.N.W., 15° N.W., 10° W.S.W., 30° W.N.W.; from Beaver Tail Light north to Austin's Cove on the west side of the island: 30°, 35°, 40°–45°, all W.N.W.; at 124, 40° W.; at 125, 40° N.N.W.; at 126, 40°–45° N.W.; and at 127,—N.N.W. The following observations were made: From 109 to 120 the schist is often minutely plicated, one specimen showing 7 plications to the inch, and sometimes folded at high angles. At 117 is a sheet of schist, broken off from the adjoining outcrop, measuring about $5' \times 5' \times 6''$ which is folded twice at right angles. At 119 occur veins of quartz, with chlorite and ferruginous, crystalline calcite like those between 106 and 108. The schists and slates are very finely laminated, greenish gray, waxy, possibly slightly talcoid or hydro-micaceous. The minute nodules of siderite vary in size and in distribution. Between 119 and 120 the schists are dark gray; at 120, striped light and dark across the bedding. Between 120 and 121 is a bed or vein 10 feet thick of a much decomposed, micaceous, siliceous and ferruginous rock. At 122, the dark gray slates recur with cubical pyrite, and continue to Lion's Head, with one vein of quartz and calcite. The dark gray schist passes both vertically and horizontally into the light colored. At Lion's Head, are striped schists. At 123 there is a vein 1 to 3 feet thick, running N.W.–S.E. at high angle, of argillaceous quartz with cubical pyrite and crystalline calcite. Near Beaver Tail Light, the beds are slightly ochraceous; on the west side, north of the Light, they are alternately light or dark or striped; at 124, a vein like that of 123. At 126 the oxidized nodules of siderite stand out on the weathered schist which is finely veined with quartz. The largest nodules measure 3–4 mm. in diameter. At 127, the summit of a 120 foot hill, is an outcrop, traceable for about 1200 feet, consisting at the south end of siderite schist which passes northward and horizontally into a micaceous schist.

[To be continued.]

ART. XXVIII.—*On the Crystalline Form of the supposed Herderite from Stoneham, Maine;* by EDWARD S. DANA.

IN the preceding number of this Journal (III, xxvii, 135), Messrs. Hidden and Mackintosh have described a mineral from Stoneham, Maine, which, as they show, is probably identical with Haidinger's herderite. The first notice of this mineral was given by Mr. Hidden in the January number (p. 73). Mr. Hidden has had the kindness to place in my hands the best of his specimens for crystallographic description, and I have also to thank Mr. George F. Kunz, of New York, for additional material furnished me for the same object. The study of these specimens has enabled me to make out the form of the mineral with reasonable accuracy.

The crystals examined were mostly quite small, varying from 1 or 2 to 3^{mm} in diameter, though there were also a few larger crystals. A preliminary examination served to confirm the results of Mr. Hidden that the form of the Maine mineral approximated closely to that of the herderite from Saxony. The position in which the crystals are placed is consequently made to correspond with that of the herderite as given by Brooke and Miller (p. 490) and in Dana's System of Mineralogy (5th ed., p. 546).* The measurements and the optical examination go to prove that the crystals belong to the orthorhombic system.

The crystals are prismatically developed in the direction of the brachydiagonal axis, as shown in the figures (1, 2, 3), and they are ordinarily terminated at both extremities of this axis. The commoner forms are those of figures 1 and 2, the habit varying according to the development of the pinacoids *b* and *c*. Occasionally more complex forms, as that in figure 3, are seen, and in one or two cases the crystals were further modified by several minute planes not there represented; these are *l*, *n*, *q* (see below), and two or three others which could not be determined with certainty.

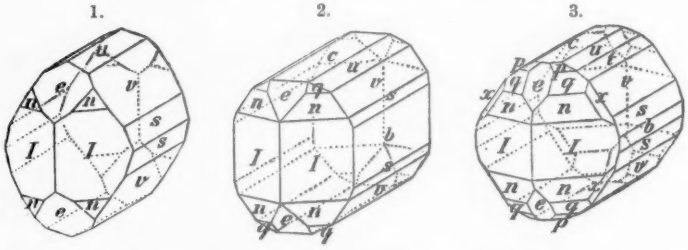
The observed planes are fifteen in number, viz:

O (001, *c*), *i*-$\breve{\imath}$ (010, *b*); prisms *I* (110), *i*-$\breve{2}$ (120, *l*), *i*-$\breve{3}$ (130, *n*); macrodome $\frac{3}{2}$-$\breve{\imath}$ (302, *e*); brachydomes 1-$\breve{\imath}$ (011, *u*), $\frac{3}{2}$-$\breve{\imath}$ (032, *t*), 3-$\breve{\imath}$ (031, *v*), 6-$\breve{\imath}$ (061, *s*); pyramids 1 (111, *p*), $\frac{3}{2}$ (332, *q*), 3 (331, *n*); 3-$\breve{2}$ (362, *x*); 3-$\breve{3}$ (131, *y*).

Considerable difficulty was found in obtaining satisfactory fundamental angles, and a large number of measurements were

* By Haidinger, and after him Naumann, $t=i$-$\breve{\frac{3}{2}}$ (230), and $I=\frac{3}{2}$-$\breve{\imath}$ (032).

made before these could be settled upon. The reason for this is that the planes, though in most cases bright, seldom afford sharp well-defined reflections. Their surfaces are sometimes irregularly striated, again uneven as if broken, and still more



frequently they are covered by minute pyramidal prominences. In the last case it was common to obtain two or more equally bright reflections, and these prominences mark the tendency of the crystallization to produce "vicinal" planes in the place of the simple plane whose position they so nearly occupy. Similar elevations have been observed on the surfaces of the crystals of many species (see the memoirs of Scharff, Sadebeck and others), and very recently Dr. Max Schuster has made a minute and careful study of them on the crystals of danburite from the Scopi (Min. Mitth., 1883, 397), and has discussed their significance in the development of the crystalline form. It is not considered necessary to go into the subject here, but it is evident that, in such cases as the above of multiple reflections, neither one gives the true position of the plane in question; in general it was found that the mean of the two measurements corresponded to it more closely.

The angles finally selected as the basis of calculation were those most nearly free from the irregularities named, the surfaces of the planes being smooth and the reflections tolerably sharp and well defined. These angles are:

1-½ ∧ 1-½ over *O*	$(011 \wedge 0\bar{1}1)$	=45° 54′
1-½ ∧ 3 adj.	$(011 \wedge 331)$	=57° 7′

The axial ratio calculated from these angles is

$$\breve{a} : \bar{b} : c = 1 : 1{\cdot}6114 : 0{\cdot}6823 \quad \text{or} \quad 0{\cdot}6206 : 1 : 0{\cdot}4234$$

and the following list gives the most important of the calculated angles.

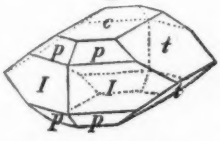
$O \wedge 1\text{-}\breve{\imath}$,	001 ∧ 011 =	22° 57′	$I \wedge I$ ov. $i\text{-}\bar{\imath}$,	110 ∧ $1\bar{1}0$ =	63° 39′
∧ $\frac{3}{2}\text{-}\breve{\imath}$,	∧ 032 =	32 25	$i\text{-}\breve{2} \wedge i\text{-}\breve{2}$ ov. $i\text{-}\breve{\imath}$,	120 ∧ $\bar{1}20$ =	77 43
∧ 3-$\breve{\imath}$,	∧ 031 =	51 47	$i\text{-}\breve{3} \wedge i\text{-}\breve{3}$	130 ∧ $\bar{1}30$ =	56 29
∧ 6-$\breve{\imath}$,	∧ 061 =	68 31	$\frac{3}{2}\text{-}\bar{\imath} \wedge \frac{3}{2}\text{-}\bar{\imath}$ ov. O,	302 ∧ $\bar{3}02$ =	91 20
∧ $\frac{3}{2}\text{-}\breve{\imath}$,	∧ 302 =	45 40	$1\text{-}\breve{\imath} \wedge 1\text{-}\breve{\imath}$	011 ∧ $0\bar{1}1$ =	45 54*
∧ 1 ,	∧ 111 =	38 46	$\frac{3}{2}\text{-}\breve{\imath} \wedge \frac{3}{2}\text{-}\breve{\imath}$	032 ∧ $0\bar{3}2$ =	64 51
∧ $\frac{3}{2}$,	∧ 332 =	50 18	$3\text{-}\breve{\imath} \wedge 3\text{-}\breve{\imath}$	031 ∧ $0\bar{3}1$ =	103 35
∧ 3 ,	∧ 331 =	67 27	$6\text{-}\breve{\imath} \wedge 6\text{-}\bar{\imath}$	061 ∧ $0\bar{6}1$ =	137 2
∧ 3-$\breve{2}$,	∧ 362 =	58 30			
∧ 3-$\breve{3}$,	∧ 131 =	55 16	$1 \wedge 1$ ov. $1\text{-}\bar{\imath}$,	111 ∧ $1\bar{1}1$ =	38 33
			$1 \wedge 1$ ov. $1\text{-}\breve{\imath}$,	111 ∧ $\bar{1}11$ =	64 18
$i\text{-}\breve{\imath} \wedge I$,	010 ∧ 110 =	58 11	$1 \wedge 1$ ov. O,	111 ∧ $\bar{1}\bar{1}1$ =	77 32
∧ $i\text{-}\breve{2}$,	∧ 120 =	38 51			
∧ $i\text{-}\breve{3}$,	∧ 130 =	28 14			
∧ 1,	∧ 111 =	70 43	$3 \wedge 3$ ov. $3\text{-}\bar{\imath}$,	331 ∧ $3\bar{3}1$ =	58 17
∧ $\frac{3}{2}$,	∧ 332 =	66 4	$3 \wedge 3$ ov. $3\text{-}\breve{\imath}$,	331 ∧ $\bar{3}31$ =	103 24
∧ 3,	∧ 331 =	60 51	$\frac{3}{2}\text{-}\bar{\imath} \wedge 1\text{-}\breve{\imath}$	302 ∧ 011 =	49 57
∧ 3-$\breve{2}$,	∧ 131 =	43 37	$\frac{3}{2}\text{-}\bar{\imath} \wedge 3$	302 ∧ $33\bar{1}$ =	72 56
∧ 3-$\breve{3}$,	∧ 362 =	48 24	$\frac{3}{2}\text{-}\bar{\imath} \wedge 3$	302 ∧ 331 =	33 47
			$1\text{-}\breve{\imath} \wedge 3$	011 ∧ 331 =	57 7*

For comparison with the calculated angles the following results of measurement may be given, only the most reliable being taken.

	Measured.				Required.
110 ∧ $1\bar{1}0$ =	63° 38′	63° 37′	63° 40′		63° 39′
302 ∧ $30\bar{2}$ =	88 45	88 38	88 23	88° 27′	88 40
011 ∧ $0\bar{1}1$ =	45 54*			45 50	45 54
031 ∧ $0\bar{3}1$ =	103 39				103 35
061 ∧ $0\bar{6}1$ =	137 1½				137 2
331 ∧ $3\bar{3}1$ =	58 13			58 12	58 17
331 ∧ $33\bar{1}$ =	44 52			44 42	45 5
302 ∧ 011 =	49 39			49 37	49 57
302 ∧ 331 =				33 53	33 47
302 ∧ $33\bar{1}$ =	73 7				72 56

Comparison with herderite.—The only detailed account of the crystalline form of the original herderite is that of Haidinger already referred to. Figure 4 represents the form given by him, but redrawn so that the vertical prism is in its ordinary position (compare figure 454, p. 546 in Dana's Mineralogy). It will be seen that the habit does not correspond very closely with that of the Maine mineral. The planes given for herderite are O (001, *c*), $i\text{-}\breve{\imath}$ (010, *b*), I (110), $\frac{3}{2}\text{-}\breve{\imath}$ (032, *t*), 6-$\breve{\imath}$ (061, *s*), 1 (111, *p*), 3 (331, *n*), 4 (441, *o*). By comparing this list with that given above, it will be seen

4.



that all of these planes except the macropinacoid and the pyramid 4 occur on the Maine mineral, while with the latter there are eight not given for herderite. The axial ratio given for herderite is:

$$\breve{a} : \bar{b} : c = 1 : 1{\cdot}5971 : 0{\cdot}6783 \quad \text{or} \quad 0{\cdot}6261 : 1 : 0{\cdot}4247$$

The following list will show how far the angles correspond:

		Maine phosphate.	Herderite.
$I \wedge I$,	$110 \wedge 1\bar{1}0$,	63° 39′	64° 7′
$1\text{-}\breve{x} \wedge 1\text{-}\breve{x}$,	$011 \wedge 0\bar{1}1$,	45 54	46 2
$6\text{-}\breve{x} \wedge 6\text{-}\breve{x}$,	$061 \wedge 0\bar{6}1$,	137 2	137 8
$O \wedge 1$,	$001 \wedge 111$,	38 46	38 41
$O \wedge 3$,	$001 \wedge 331$,	67 27	67 25
$1\text{-}\breve{i} \wedge 1\text{-}\breve{i}$	$101 \wedge \bar{1}01$,	68 37	68 18

These angles are in the four principal zones and serve as well as a much larger number to show the relation of the two minerals. It will be seen that the angles in the brachydome series approximate very closely, as also those of the unit pyramids, while the macrodomes and vertical prisms vary somewhat. In other words the ratio (compare the axial ratios given) of the axes $\bar{b} : c$ is nearly the same, while those of $\breve{a} : c$ and $\breve{a} : \bar{b}$ differ slightly. This variation is a real one and not caused by error in the assumed fundamental angles; for example for herderite the angle of the macrodome is $302 \wedge 30\bar{2} = 89° 0'$, while on the Maine phosphate the measured values of this angle varied in the extreme cases from 88° to 88° 45′, the most trustworthy angles being those given in the table above. What degree of dependence is to be placed on the original angles of Haidinger cannot be determined, but it may be mentioned in this connection that Groth (Min. Samml. Strassburg, p. 259) states that his measurements on an original specimen confirmed those of Haidinger. Neither the variation in habit nor in angle is, however, sufficient reason for separating the two minerals, but we must conclude that the results of the crystallographic study of the Maine phosphate serve to strengthen the probability of its identity with the Saxon mineral. The question, however, cannot be regarded as settled until something more definite is known about the chemical composition of the latter mineral. It is much to be hoped that one of the few existing authentic specimens will afford the means of at least determining whether it contains aluminum as suspected by Plattner, or beryllium like the mineral from Stoneham.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a Relation between the Molecular weight of Liquids and their Velocity of Evaporation.*—On distilling successively in the same apparatus given volumes of benzene and of water, Schall found that, even when the boiling was maintained as nearly uniform as possible, very different weights of these two substances passed over in the same time. Even in a rough experiment, the quantity of benzene in the receiver was double that of the water. With a view to give the experiment greater exactness, the time of evaporation of equal volumes of these liquids was carefully determined. Knowing then the density of the liquids at the boiling point, their weights could be calculated and hence the exact time of evaporation of equal weights. On comparison, the values thus obtained appeared to be very nearly in the inverse ratio of the molecular weights of the liquids employed. Thus benzene, with a boiling point of 79·2° and a density of 0·8136, evaporated in 12·7, 12·95 and 12·3 minutes; while the same volume of chloroform, boiling point 61·5° and density 1·4048, evaporated in 14·3, 14·5 and 14·3 minutes. Or, reduced to equal weights, in 8·25, 8·4 and 8·28 minutes. Since $m : m' :: t' : t$, the first value gives for the molecular weight of chloroform 119·64, the second 120·25, and the third 115·88; the true value being 119·5. Benzene, when compared with carbon disulphide, boiling point 45·3° and density 1·2212, evaporated in 12·3 minutes, while the same volume of CS_2 required 19 minutes; or 12·66, reduced to equal weights. This gives a molecular weight of 75·79, in place of 76. Water, boiling point 99° and density 0·9596, evaporated in 64 minutes; or 54·26 minutes reduced to equal weights. This gives a molecular weight of 17·68 instead of 18. Moreover, the ratio of the volumes of two liquids evaporated in equal times is the ratio of their molecular volumes. Thus the ratio for benzene and chloroform above given, is 1·126 : 1; whence 1·126 : 1 : : 95·94 (the molecular volume of benzene) : 85·2 (the molecular volume of chloroform); Schiff obtained 84·65. The author has further observed that on comparing Regnault's values of the heat of vaporization of several liquids, these numbers decrease as the molecular weight increases. From which, of fifteen liquids whose heat-data are known, thirteen fall readily into five groups in which the product of the heat of vaporization into the molecular weight is approximately constant. Thus water gives $536·67 \times 18 = 9660·06$; while alcohol gives $214·3 \times 46 = 9857·8$. Acetone gives 7523·76, chloroform 7289·5 and carbon tetrachloride 7161. Ethyl oxide 6711·8, carbon disulphide 6361·2 and ethyl chloride 6128·79. Stannic chloride 11736·4, arsenous chloride 12292·99 and ethyl acetate 12820·72. Phosphorous chloride 8970·5 and ethyl iodide 8938·8.

The remaining two are amyl alcohol, which gives 17954·64 and bromine, 7963·2. These do not seem to belong to any of the above groups, unless the latter be placed in that containing acetone.—*Ber. Berl. Chem. Ges.*, xvi, 3011, Jan., 1884. G. F. B.

2. *On the use of Nitrogen iodide in Photometry.*—In experimenting with nitrogen iodide, prepared by the action of iodine upon an aqueous solution of ammonia, GUYARD has observed that this substance is immediately decomposed in sunlight, nitrogen gas being evolved with effervescence. The minimum action takes place in the violet, the maximum in the blue. In the red-orange the action is sensibly the same as in white light, and in the yellow it is somewhat superior to white. The result appears not to be an effect of heat, since it is the same when the containing vessel is immersed in water kept at a low temperature, or in an athermanous solution. When placed in pure water, and exposed to light, the nitrogen iodide decomposes at first tranquilly, then explodes violently. But immersed in a solution of ammonia of 22° Baumé, it decomposes quietly, no explosion taking place, the rapidity being proportional to the intensity of the light. This suggested the use of this reaction in photometry. But the result may be obtained more simply by acting with iodine upon ammonia at 22° B., the nitrogen evolved in a given time being measured. Nitrogen iodide is produced equally in the light and in the dark; being produced in the light more rapidly than it is decomposed. One-half the iodine forms nitrogen iodide the other half ammonium iodide; traces of ammonium iodate being also produced. For photometric purposes the nitrogen set free may be estimated either by weight or by measure, one gram of pure iodine being employed for 25 to 30 c.c. of ammonia at 22° B. The author gives the name *isophore* or *phosisotime* to the unit of luminous intensity represented by fourteen thousandths of a milligram of nitrogen evolved per hour. This is equivalent to 1·7 c. c. (containing aqueous vapor and ammonia) at 15° and 76 cm. in the photometric burette. The decomposition of the nitrogen iodide by the action of light is given thus: $(NH_2I)_2 = NH_4I_2 + N$; ammonium di-iodide and nitrogen, with a trace of iodate, being the sole products.—*Bull. Soc. Chim.*, II, xli, 12, Jan., 1884. G. F. B.

3. *On the Production of Hydroxylamine from Nitric acid.*—DIVERS has investigated the reducing action of various metals upon nitric acid, and finds that the action of tin, zinc, cadmium, magnesium and aluminum gives rise to the production of hydroxylamine, especially in presence of hydrochloric or sulphuric acid. The function of the second acid is to decompose the nitrate as fast as it is produced, and so (1) to hold the hydroxylamine in a more stable state, (2) to preserve it from the destructive action of nitrous acid by preventing the formation of this acid from the reaction of the metal on the nitrate, and (3) to determine the reduction of the nitric acid to hydroxylamine by supplying the hydrogen for reproducing it. Metals he divides into two classes according to their action on nitric acid. In the first class are

silver, copper, mercury and bismuth. These metals form nitrite, nitrate and water, and exert no further action, producing neither ammonia nor hydroxylamine. They decompose the nitric acid into hydroxyl and nitroxyl combining with these radicals to form hydrate and nitrite, which by secondary reactions become water, nitrous acid and metal nitrate. They therefore separate nitrogen from oxygen (hydroxyl) in decomposing nitric acid, and not hydrogen from oxygen. In the second class are tin, zinc, cadmium, magnesium, aluminum, lead, iron and the alkali metals. These form ammonia and generally hydroxylamine, but do not produce nitrous acid or nitrite with free nitric acid. On the other hand they readily form nitrite by acting on their own nitrate. Two actions are noted: 1st, upon seven molecules of acid separating as hydroxylamine, the hydrogen of six of them by forming nitrate and leaving the seventh converted to water and the said hydroxylamine; 2d, they combine with hydroxylamine to form metal-ammonium hydrate which decomposes with water into metal-hydrate and ammonia. The author considers that nitrites have a constitution indicated by the name "nitronates," the metal being directly united to their nitrogen. The radical is the same as that existing in nitrates $-NO_2-$, these being its metal-oxyl compounds.—*J. Chem. Soc.*, xliii, 443, Dec., 1883. G. F. B.

4. *On the Oxidation of Phosphorus at low temperatures.*—It having been asserted by Irving that phosphorous oxide, prepared by passing a current of dry air over melted phosphorus, is decomposed when exposed to sunlight into amorphous phosphorus and phosphoric oxide, COWPER and LEWES have repeated the experiments with a view to verify them. They obtained a perfectly white deposit in the farther chambers of the tube, and on sealing off two of these and exposing one to the light while the other was kept in darkness, they observed that the former became brown in a few hours, while the latter remained white. On examining the white mass with a lens, it was seen to be filled with minute crystals, and on shaking a portion into the air it at once took fire. Another portion of the white deposit treated with water and filtered left a residue of phosphorus on the filter which took fire on drying. On analysis the white deposit proved to be a mixture of phosphoric oxide 71·0, phosphorous oxide 9·6 and phosphorus (by difference) 19·3 per cent. The so-called phosphorous oxide of Irving is therefore essentially phosphoric oxide containing considerable free phosphorus.—*J. Chem. Soc.*, xlv, 10, Jan., 1884. G. F. B.

5. *On the Constitution of Benzene.*—About eighteen years ago KEKULÉ suggested the hypothesis that all aromatic compounds had as a nucleus six tetrad carbon atoms united in a closed ring. The marvelous fruitfulness of this hypothesis has well nigh re-created organic chemistry. In 1879, Gruber produced an acid by treating protocatechnic acid with nitrous acid, which he called carboxytartronic acid, to which he assigned the formula $C_4H_4O_7$,

or $OH-C\begin{cases}COOH.\\COOH.\\COOH.\end{cases}$ Barth, the following year, produced it from pyrocatechin by similar treatment, and maintained that its formation proved that in benzene one carbon atom must exist united to three others; contrary to the hypothesis of Kekulé. This latter chemist has now made an elaborate investigation of the so-called carboxytartronic acid, and has succeeded, 1st, in producing from it, by the action of reducing agents, tartronic, inactive tartaric and racemic acids; and 2d, in preparing it from tartaric acid. The insoluble characteristic sodium carboxytartronate prepared from tartaric acid, is identical with that obtained from pyrocatechin. It is therefore clear that carboxytartronic acid cannot have the constitution hitherto ascribed to it, and hence is wrongly named. It should not be called carboxytartronic acid nor oxymethin tricarbonic acid as proposed by v. Meyer; first because it does not possess the constitution expressed by these names; and second, because these names should be reserved for their proper acids. Although the exact formula is uncertain owing to the difficulty of obtaining the water of crystallization, yet no doubt exists that this acid stands in simple relation to tartaric acid and is dioxytartaric or tetroxysuccinic acid. Since, therefore, it contains no carbon atom united to three other carbon atoms, its formation from pyrocatechin is no argument against the benzene ring. Although this formation can be explained by either the hexagonal or the prismatic formula, the author believes that it is more easily explained by the former than by the latter.—*Liebig's Ann.*, cci, 230, Oct., 1883. G. F. B.

6. *Observations on Phosphoresence, and a new phosphorescent eye-piece.*—E. Lommel places in the plane of the cross hairs of an ordinary spectroscope a piece of microscopic slide glass, one portion of which is covered with a thin layer of Balmain's paint, or other phosphorescent material. In certain cases the phosphorescent substance is contained in a very fine powder between two such slides. It is found that the phenomenon can be observed through this layer as well as by observing it on the side which receives the light. The slit of the spectroscope is suitably modified and the solar spectrum is thrown upon the phosphorescent slide after it has been subjected to daylight or to any source of light. The phenomena described by H. Becquerel can then be readily studied. The dark bands in the ultra red are shown to be true absorption bands due to the phosphorescent substances employed. By passing the red rays of the spectrum through red glass the ultra red portion is made visible by a greenish-blue phosphorescent light. By allowing the spectrum to fall on one portion of the phosphorescent slide and extinguishing it on a lower portion one can study the light bands and the dark bands of phosphorescence together. The method of increasing the visibility of the ultra red is closely analogous to that of fluorescence by means of which the ultra violet is made visible. If the wave-

length of the D line is taken as 0·589 mikron, the first characteristic dark band in the phosphorescent spectrum lies between 0·942 and 0·861, and the second between the wave-lengths 0·804 and 0·715. A greenish-blue phosphorescing sulphide of calcium gives a more vivid spectrum than Balmain's paint. A plate covered with this substance and kept in the dark for four days will show the bright phosphorescent ultra red spectrum in a beautiful manner, while Balmain's preparation of sulphide of calcium scarcely shows it after being two days in darkness. Other preparations of sulphide of calcium were experimented with, including a sky-blue preparation, but these were all inferior to the greenish-blue preparation. It was found that the phosphorescent light is stronger during the action of the exciting rays than afterward, and the distribution is also different in the two cases.—*Ann. der. Physik und Chemie*, 1883, No. 12[b], pp. 847–860. J. T.

7. *Earth Currents.*—In reply to certain criticisms of M. Larroque, M. E. E. Blavier, who is engaged in studying electrical effects upon a line between Nancy and Paris, says, in substance: The potential of a point on the earth's surface is modified by many accidental circumstances, such as the discharge of a storm cloud, etc.; but this variation is infinitely short and equilibrium is soon re-established, and the slight changes give no trace upon a strip of photographic paper on which the space given to one hour is only $0^{m}{\cdot}01$. It is claimed by M. Larroque that sufficient attention has not been paid to polarization currents. The plates employed were masses of iron, which it is true gave a contrary electromotive force of about $\frac{1}{10}$ of a volt, while the earth currents observed were often 3 to 5 volts. The polarization is sensibly constant during a certain portion of the time of observation and can be taken into account in cases of registration. M. Larroque believes that the static potential of the earth at the two contacts should be taken into account. M. Blavier has not occupied himself with this question. In reply to the point that the resistance of the earth between the two stations varies with different conditions, it is replied that the resistance of the earth around an earth-plate in ordinary telegraph lines when communication is well established, does not exceed generally 40 ohms, while the experimental line adopted by M. Blavier had a resistance of 10,000 ohms. M. Larroque believes that uncovered aerial telegraphic lines are unsuitable for the study of earth currents; but M. Blavier finds no difference between an aerial line and a submarine cable. In reply to the points that it is necessary that the line should be formed of a wire of small resistance, non-magnetic, well insulated and absolutely free from humidity, M. Blavier states that it is necessary to employ a circuit of high resistance, that the magnetic properties of the iron have no effect, and that the insulation of an ordinary telegraphic iron gives the same result as a submarine cable. It was found that the battery earth of the telegraphic system of Paris did not affect the results appreciably, and that earth currents could be observed on short lengths of

line. The curves furnished on a line from Paris to Chalons were compared with those given by a line from Rue de Grenelle, in Paris, to the Porte de Flandres, and were found to exhibit the same variations, with only slight variations due to the lines not holding exactly the same direction.—*Comptes Rendus*, Dec. 31, 1883, pp. 1551–1553. J. T.

8. *Heat in iron due to periodically changing magnetic force.*—The heat noticed has been attributed by some investigators to the movements of the magnetic molecules, and hence has been called heat of magnetic friction. Other investigators think that this heat is due almost entirely to electro-magnetic induction in the mass of iron. E. WARBURG and L. HÖNIG have taken up the subject and their experiments lead them to believe that a large part of the heat is due to magnetic friction. The magnetizing coil and the entire apparatus were placed in a carefully constructed calorimeter with double walls filled with fine pieces of ice. The iron, generally in the shape of a bundle of iron wires, was enclosed in the bulb of what was practically an ether thermometer. The leading principle of the method adopted was to heat the iron by two cyclic processes. In the first cycle the magnetizing force varied from 0 to $+k$; in the second cycle from $-k$ to $+k$. k was 170 times the horizontal component of the earth's magnetism in Freiburg. If the heat produced depended only upon the electrical resistance of the iron, and if the coercitive-force of the iron was zero the authors maintain that the heat of the double cycle should be twice that of the single cycle. In one case, in which they used a thick bar of iron, this was so; in other cases the ratio of the heat produced in the double to that in the single cycle, was greater than two. The authors examined the sources of error that might arise from the change in character of the temporary and permanent magnetism due to change in direction of the magnetizing currents. They also examined how much heat was due to the application of Carnot's principle, pointed out by Thomson, namely, that a production or absorption of heat is produced according as the magnetizing function decreases or increases with the changing temperature. The general conclusion arrived at is that a large proportion of the heat observed, nearly 75 per cent, is due to magnetic friction.—*Ann. der Physik und Chemie*, No. 12[b], 1883, pp. 814–835. J. T.

9. *Principles of Theoretical Chemistry, with Special reference to the Constitution of Chemical Compounds*; by IRA REMSEN, Professor of Chemistry in the Johns Hopkins University. Second edition, thoroughly revised and enlarged. 8vo., pp. xii, 242. Philadelphia, 1883. Henry C. Lea's Son & Co.—This excellent little book of Professor Remsen's may fairly be considered a protest uttered against the now prevalent notion that the science of Chemistry lies chiefly in its formulas. Its key-note, stated on page 100, is as follows: "It cannot be denied that we are now in a period of Chemistry which may fairly be called one of *formula worship*. By weaker minds more value is attached to a formula

than to that which it is intended to represent. In consequence of this truth, it has happened that a large number of chemists have regarded the determination of a formula for a compound as the great object to be accomplished and forgotten that what we ought to know and what is of vastly greater importance for the science is the chemical conduct of the compound." Hence the author states in the preface: "I have endeavored to discuss in an impartial way, as objectively as possible, the principal hypotheses which at present play important parts in the science of chemistry. As, strictly speaking, we have no theory of chemistry, the hypotheses are more or less disconnected; and as there is no general theory to keep them in check, some of them have assumed a variety of forms." What, precisely, is meant by the term "constitution" on the title page, he tells us on page 232: "A study of the preceding chapters on constitution will show that no absolute meaning is to be attached to the word. Constitutional formulas are those which suggest certain reactions and recall analogies. The formula CH_3—OH does not mean that hydroxyl (OH) is necessarily present in the compound or that CH_3 is present, but that the different parts of the compound bear such relations to each other that when the compound is decomposed it acts as if the parts were united as the formula indicates. The formula suggests possibilities; it may not represent realities." The book is therefore a valuable contribution to the chemical literature of instruction; and particularly at this time when so strong a tendency exists to over-value chemical hypotheses and under-value chemical reactions. That in so few years a second edition has been called for indicates that many chemical teachers have been found ready to endorse its plan and to adopt its methods. In this edition a considerable proportion of the book has been rewritten, much new matter has been added and the whole has been brought up to date. We observe, however, that the somewhat cumbrous terms "hydroxide" and "anhydride" have been retained, in place of the simpler ones "hydrate" and "oxide," which seem more in harmony with chemical nomenclature generally. We earnestly commend this book to every student of chemistry. The high reputation of its author assures its accuracy in all matters of fact. And its judicious conservatism in matters of theory combined with the fullness with which, in a small compass, the present attitude of chemical science toward the constitution of its compounds is considered, gives it a value much beyond that accorded to the average text books of the day.

II. Geology and Natural History.

1. *Human foot-prints on sandstone near Managua, in Nicaragua;* by George H. Johnson, Professor of Mathematics and Engineering at Leon, Nicaragua. (From a letter dated College of Leon, Leon, Nicaragua, Central Am., Nov. 5, 1883, to Professor George H. Cook, of New Brunswick, N. J., and communicated

by the latter.)—Before coming to Leon we remained six weeks in Managua studying the language. While there I learned that foot-prints had been found on a sandstone at a quarry in the vicinity, and took the first opportunity for visiting the quarry. The quarry is situated southwest of the School of Arts and about a quarter of a mile west of the *Plaza*. Around the quarry were many blocks of sandstone about one cubic foot in size; these had just been excavated and quite a number of them contained tracks which were undoubtedly human foot-prints. They looked exactly like the impressions of bare feet which may be seen at any time on the sandy beach of Lake Managua, which is only a few rods from the quarry. The bottom of the foot-print was generally about two-thirds of an inch below the even surface of the stone, and some of the impressions were quite distinct, showing the form of each toe. Most of the tracks were large enough for a man, but some of them were evidently made by a child. I found by inquiry that when the stratum of sandstone was exposed three parallel series of tracks were seen, all of them directed from the east toward the west. I examined the strata overlying the sandstone containing the tracks, and the vertical section (from the surface downward), as shown at the quarry is as follows:

Unsolidified volcanic conglomerate, 3 layers, 3½ feet.
Stratified sandstone, 2 layers, 2 feet.
Greenish-brown clay, 14 inches.
Sand, 1½ feet.
Yellowish-brown clay, 14 inches.
Brown clay, 6 inches.
Sandstone, 3 layers, 2·3 feet.

All the beds are approximately horizontal and of nearly uniform thickness. It will be seen from the section that the tracks are found about twelve feet below the surface. Some of the overlying beds contain numerous arrow-heads and other relics which are quite unknown among the Spanish-speaking Indians who now constitute the mass of the population.

All the western part of Nicaragua is highly volcanic and probably had its origin during the Quaternary period. There is some reason for supposing that Lake Managua, as well as the lake of Masaya, was formed by the sinking of a great volcano.

The beds overlying the tracks are undoubtedly either directly or indirectly of volcanic origin. That is, the beds may be composed of volcanic matter originally deposited in its present location and then partly solidified by pressure, or the matter may be disintegrated lava, etc., which was deposited in water. The latter hypothesis is supported by the fact that that part of the country has sometimes been inundated by great floods during the rainy season.

2. *On the relative ages of certain River-valleys in Lincolnshire;* by A. J. JUKES-BROWNE. (Quart. Journ. Geol. Soc., xxxix, 4, 1883, 596.)—The author sustains the general theory of Jukes, that in a region of parallel escarpments the drainage (im-

plied consequent) comprises (1) cross-streams in the direction of dip (and implied slope), which are the older, and (2) longitudinal tributaries parallel with the escarpments and strike, which are the newer; but he assails the unessential though indubitable corallory that no longitudinal tributary can ever intercept and incorporate the lowest of the pre-existent cross-streams. Assuming a dip and slope not orthogonal to the escarpments—a condition incompatible with Jukes's theory in its simplest form—he argues (and demonstrates, from an ill-considered example adduced by Jukes), that the longitudinal stream flowing into the sea may so extend its course as to interrupt and absorb a number older cross-streams. Additional examples are described originally, and discussed at length. W. J. M.

3. K. J. V. Steenstrup *on the Glacier and Glacier-ice of North Greenland.* 84 pp. 8vo, with 7 plates and a colored geological map.—This memoir relates to the West Greenland region, between the parallels of 69° (near Jakobshavn) and 72° 30′ N., which includes the island of Disko. The fine map shows the limits of the inland or interior ice; the limits of the many glacier-streams that descend from the interior ice into the heads of the long fiords; other smaller glaciers descending from the high land within the coast region; the position of the Carboniferous beds along the northern and western coasts of Disko, on the peninsula of Nugsuaks next north, and on Upernavik and at other points farther north; the distribution of the trap, the chief surface rock apparently of Disko and other coast islands and peninsulas; the localities about Disko, and the peninsula north of it and elsewhere, of the nickeliferous (or meteorite-like) iron, part of the iron in place; and other points of interest. The plates are phototypes and highly instructive.

4. *Malesia*, auct. Odvardo Beccari.—The three earlier parts of this fine work were published in the years 1877–8, and were duly noticed in this Journal. The indefatigable author has now sent us the fourth part, which completes the first volume, a quarto of 304 pages, and with 28 excellent lithographic plates. The work is devoted, as we know, to the publication of the author's own botanical collections, observations and discoveries upon the plants of Indo-Malesia and Papua, during his travels in those regions in the years 1865–1876. In the part now issued Dr. Engler of Kiel has elaborated and illustrated the *Araceæ*. A. G.

5. *Thoughts upon Botanical Taxonomy. Pensées sur la Taxonomie Botanique;* par T. Caruel.—A memoir by the most accomplished systematist in phænogamous botany in Italy, now professor in Florence, presented to the Lincean Academy in 1881, published the following year in its Scientific Transactions, in Italian, now re-edited by the author, in French, and published during the past year in Engler's Botanische Jahrbücher, the first portion in the fourth, the remainder in the fifth volume. The separate issue fills a little more than a hundred octavo pages. It is a treatise upon the classification of plants; which the author

well insists should remain upon a morphological basis, without mixture of other considerations. And his strength is mainly devoted to a natural arrangement of the families (orders of Jussieu) under more comprehensive orders, cohorts and classes, etc. Of course he begins the series of Phanerogamæ, class Angiospermæ with the Monocotyledones. We should all do that now, if we had to begin anew, and if we keep Gymnospermæ as a class, so as to give the latter its proper position between the higher Cryptogams and the Angiospermous Dicotyledones. Of course, also, the artificial divisions of *Polypetalæ*, *Gamopetalæ* and *Apetalæ* are thrown aside. M. Caruel replaces them with his cohorts Dichlamydanthæ, Monochlamydanthæ and Dimorphanthæ. The first includes Gamopetalous and Polypetalous orders generally; but the second has all the Candollean orders from Ranunculaceæ to Fumariaceæ, the Cactaceæ, Portulaccaceæ, Rhamnaceæ, etc., etc.; the third has Begoniaceæ, Euphorbiaceæ, Urticaceæ, etc., as well as the Amentaceous orders. A class, Anthospermæ, of equivalent weight to Angiospermæ and Gymnospermæ, is interposed between them, and consists only of the order Spermifloræ (Loranthaceæ and Viscaceæ). We need not present the new arrangement of what used to be called Cryptogamia. Looking only at the Phanerogamæ, our only remark need be that such essays are full of interest, perhaps of future promise; but that none of the recent schemes are in condition to replace the Jussiæan and Candollian arrangements with all their imperfections.

A. G.

6. *Necrologia Botanica.*—The annual record which was published in this Journal for many years has not appeared for the last three years; yet some biographical notices of deceased botanists have generally been given. From the ranks of American botanists the losses which we particularly recall to mind are the following. In the year 1880: Coe F. Austin, who died on the 18th of March, at the early age of 48. Charles C. Frost, an excellent Cryptogamist, died at Brattleboro, Vermont, March 16, at the age of 75. John Carey, whose active botanical career was in this country, in which the middle years of his long life were passed, died on the 26th of March, in his 83d year. Dr. Samuel B. Mead, of Augusta, Illinois, died November 11, at a good old age. In the year 1881, January 4, died Professor Alphonso Wood in the 71st year of his age. In 1882, Thomas Potts James, one of our few adepts in Bryology, died Feb. 22, in the 79th year of his age, leaving the venerable Lesquereux to complete the Manual of Mosses upon which these two veterans were engaged. Elihu Hall, one of the best explorers of Colorado and of Oregon botany, died September 24, at the age of 60. Happily we have no name to add to this list for the year 1883.

In the Old World the full obituary record for the year 1880 would be a long one. It would commence with the name of the venerable J. S. Tommasini of Trieste, who died upon the last day of the year preceding. It includes the name of the distin-

guished Agrostologist, General WILLIAM MUNRO, who died Jan. 29, at the age of 64; also of the two eminent Bryologists W. P. SCHIMPER, March 20, æt. 72, and of ERNEST HAMPE, Nov. 23, æt. 85; of N. J. ANDERSON of Stockholm, who had been infirm for several years, but survived until March 20; and of ROBERT FORTUNE, who died April 13, at the age of 68.

In the year 1881, died LUDWIG RABENHORST, the Cryptogamist, April 24, at the age of 76; MATTHIAS JACOB SCHLEIDEN, a foremost name forty years ago, but whose botanical career was brief, although he lived till June 23, and reached the age of 77 years; MICHAEL PAKENHAM EDGEWORTH, a brother of Maria Edgeworth, and an adept in East Indian botany, July 30, æt. 69; HEWETT COTTRELL WATSON, who so sedulously investigated the particular distribution of plants in Europe, July 27, æt. 77; PAUL GUNTHER LORENTZ, who was professor of botany at Cordoba, in the Argentine Republic, but who died at Concepcion in Uruguay, Oct. 6, æt. 52; and OTTO WILHELM SONDER of Hamburgh, who died November 21, æt. 70.

In the year 1882 we lost JOSEPH DECAISNE, February 8, at the age of 75; GEORGE H. K. THWAITES, who died at Peradeniya, Ceylon, September 11, æt. 71; and here we may also add the name of CHARLES DARWIN, who died April 19, æt. 73.

So far as we are now informed only three distinguished botanists have died during the year 1883, namely:

VINCENZO CESATI, until recently professor of Botany in the university, and director of the Botanic Garden at Naples, died there, February 13, 1883, in the 77th year of his age. He was born at Milan, of a noble Lombard family; and there most of his botanical work was done, all of a respectable but none of a very high order.

HERMANN MUELLER of Lippstadt, Botanist and Entomologist, the renowned investigator of the mutual relations of insects and flowers, as concerns the fertilization of the latter, and the adaptive modifications of the one to the other,—died on the 25th of August last, in the 54th year of his age. A brief notice of him and of his latest and most notable work was given in the October number of this Journal, p. 324; and a fuller memorial was published in Science, for Oct. 12, 1883.

OSWALD HEER, the most distinguished paleontological botanist of our time, professor of botany in the University of Zurich, died, at Lausanne, September 27, at the age of 74. An appreciative biographical notice appeared in Science, for November 2, and one may be expected in this Journal.

At home we have sustained a loss in the death of CHARLES F. PARKER, of Philadelphia, late curator of the Herbarium of the Academy of Natural Sciences, Philadelphia, an excellent local botanist, a kindly and most estimable man. He died September 7, at the age of 63. A just tribute to his memory was contributed by his associate, Mr. Martindale, to the Proceedings of the Academy of Natural Sciences, 1883, pp. 260–265. A. G.

7. Dr. George Engelmann.—Just as these pages were going to the press we are grieved to learn that our oldest associate and friend, the most venerable and eminent of our botanists, who had attained his 75th birthday on the second of February, died on the eleventh, at his home in St. Louis, after a short illness. Although his health became seriously impaired a year or two ago, yet it was of late so far restored that he was able to continue his botanical work with zeal and hopefulness, and the very last number of this Journal contained a notice of a recent publication which gave evidence of this. It must be left to a future number to place upon record some account of his life and of his many and important contributions to science. A. G.

III. Astronomy and Mathematics.

1. *Double Star observations made in* 1879 *and* 1880 *with the* 18½*-inch refractor of the Dearborn Observatory, Chicago;* by S. W. Burnham.—This reprint from the memoirs of the Roy. Astr. Soc. contains Mr. Burnham's thirteenth catalogue of new double stars, and measures of 770 others.

The several catalogues of Burnham's new stars now contain 1013 numbers. In the appendix to this memoir the author gives the number of pairs of double stars in class I (distance 0″·0 to 1″·0), and in class II (distance 1″·0 to 2″·0), occurring in the principal original double star catalogues.

	Class I.	Class II.	Total.
Burnham, catalogue of 1000 stars,	266	254	520
O. Struve, " 547 "	154	63	217
Struve, " 2640 "	91	314	405
Herschel, I, " 812 "	12	24	36
Herschel, II, " 3429 "	2	20	22
Alvan G. Clark,	14	1	15
All other observers,	40	75	

Hence, he concludes that the known pairs having a distance under 2″ are less than 1400. The principal interest will in the future he believes belong to these close pairs. Double stars below the 8th magnitude and having a distance exceeding 5″ will rarely prove of much interest.

The Milky Way has furnished to Mr. Burnham a larger number of new doubles than the same area elsewhere. In magnitude of leading component the thousand stars are distributed as follows:

0″·0 to 1″·0,	2	3″·1 to 4″·0,	11	6″·1 to 7″·0,	173	9″·0+	69
1″·1 to 2″·0,	8	4″·1 to 5″·0,	29	7″·1 to 8″·0,	303		
2″·1 to 3″·0,	11	5″·1 to 6″·0,	94	8″·1 to 9″·0,	300	Total,	1000

Particular attention is called by Mr. Burnham to the close couple $O\Sigma$ 535, (δ Equulei). The two close components of this triple star are so nearly equal in magnitude that several of the early measurements may be assumed to be 180° in error, and upon these suppositions Mr. Burnham assumes that it has an orbit whose period is 10·8 years. The distance is never more than 0″·40.

We would remark that the observations of Mr. Burnham in 1880, 1881 and 1882, together with nearly all the previous measurements of Struve and others, (corrected, if necessary, by 180°) can be satisfied by an apparent orbit of 11·6 years, the principal star central, the semimajor axis 0″·38, and semiminor 0″·10. The couple in 1883 was very close. The measures then taken are not, however, satisfied very well by this orbit. They indicate very clearly a rapid rotation.

This binary being visible to the naked eye and having probably the shortest period now known, will be watched hereafter with special interest. H. A. N.

2. *A Treatise on Projections;* by THOMAS CRAIG. 4to. Washington, 1882. — This treatise was prepared and published by the U. S. Coast and Geodetic Survey, primarily for its own use. In the several volumes of reports of the survey are very valuable papers on projections by Hunt, Schott, S. C. Peirce and others, the larger portion of them having some reference to the Polyconic projection. The present treatise is wider in scope, and treats of the whole subject of map projections. It consists of two separate portions, the first and larger one being devoted to the Mathematical Theory of Projections, and the second to the Construction of Projections.

The first section in the first part is given to the various kinds of perspective projections of a spherical surface on a plane. Then follow two sections on orthomorphic projections, or those in which figures on any one surface are represented upon any other surface in such manner that small parts in the one figure shall be similar to the corresponding parts in the other. The fourth section treats of projection by development, or, in effect, the representation in small portions of a spherical surface upon tangent cones or cylinders, which are then developed. Two chapters follow upon Zenithal and Equivalent Projections, and then three on the general Mathematical theory of the Orthomorphic, the Equivalent and the Development projections.

The second part is independent of the first, and is intended for practical use. It gives the methods of construction of the several projections, and is followed by thirty-one tables. H. A. N.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Distribution of the Magnetic Declination in the United States at the Epoch January*, 1885, with three isogonic charts and one plate. *Secular Variation of the Magnetic Declination in the United States and at some foreign stations.* (Fifth edition.) With four plates. — The above are titles of two important memoirs by Mr. CHARLES A. SCHOTT, published (as stated on p. 79 of this volume), as appendices to the report for 1882 of the U. S. Coast and Geodetic Survey, J. E. Hilgard, Superintendent. The last published isogonic chart for the United States, by J. E. Hilgard, was prepared for the epoch of 1875

(it was reproduced in this Journal, vol. xix, p. 173). The present chart is on a larger scale than the former, and being based upon a greater number of observations it differs from earlier charts in showing the local disturbances in the direction of the magnetic needle; in the case of the New England States and Missouri, for example, the minor irregularities in the distribution of the magnetism are given with considerable accuracy. The accompanying memoir gives a table, extending over upwards of forty pages, of magnetic declinations reduced to the epoch of January 1, 1885.

The memoir upon the secular variation of the magnetic declination, chiefly in the United States, the preceding 4th edition of which was published in June, 1881, gives a most valuable and interesting summary of the facts relating to the secular variation of the magnetic needle in this country, together with the enumeration of the long series of observations upon which the results are based. A special plate shows the position of the region in northeastern Maine and beyond, where the needle has reached its western elongation and become stationary; and also of that in the west, across Idaho, Nevada and Arizona, where the needle is also stationary, having reached its eastern elongation. The progressive motion of the secular change from east to west may be compared to a wave motion, and these two regions named are in opposition with respect to the phases of the phenomenon, the one corresponding to a crest, the other a trough, and the space between them representing half a wave-length. Another plate exhibits the more or less exactly known positions of the agonic line of the North Atlantic for the epochs of 1500, 1600, 1700, 1800, 1880 and 1900, and it is shown that the azimuthal motion of the isogonic system in the vicinity of this agonic line, as represented by this line, has been since 1600 in the direction of the hands of a watch.

2. *Maps issued by the Northern Trans-Continental Survey*, RAPHAEL PUMPELLY, Director.—The Northern Trans-Continental Survey, organized in 1881 in the interest of the principal railroads of the Northwestern Territories, has recently issued Map Bulletin No. 1, prepared by the Topographical Department, A. D. WILSON Chief Topographer, associated with R. W. Goode and Louis Nell. It includes the following maps: Yakima Region, W. T., in two sheets; Colville Region, W. T.; Judith Basin, Montana, in two sheets; Crazy Mountains, Montana. The maps have been excellently executed by Julius Bien, of New York.

OBITUARY.

ARNOLD HENRY GUYOT.—Professor Guyot, for many years occupying the chair of Geology and Physical Geography in the College of New Jersey, at Princeton, died on the 8th of February, in his 77th year. He was born near Neuchâtel, Switzerland, in 1807; studied at the universities of Stuttgart, Carlsruhe and Berlin, adding to theology, at the latter place, physical geography under Karl Ritter, and geology under Hoffmann; and ended

his preparation for work by studies from 1835 to 1839 at Paris. In 1839 he was called to the Professorship of History and Physical Geography at Neuchâtel, where Agassiz, his early companion, and but four months his senior, had occupied, since 1832, the chair of Natural History.

Professor Guyot held this position at Neuchâtel for ten years, and in the interval he spent much of his time in carrying on investigations, previously begun, in the physics and structure of the Alps, and the phenomena of glaciers. He made out the laws of motion in the glacier, and diverged from Agassiz in the conclusion which he reached as to the movement, attributing it to "molecular displacement mainly under the action of gravity." He was the first to discover (in 1838), the laminated character of the glacier ice. He made a special study of the bowlders that are spread over Switzerland between the Alps and the Juras, and discovered that those of different kinds of rocks were largely in lines leading up to different Alpine peaks from which they were sent off, and, after laborious explorations and comparisons involving over 3000 barometric determinations of altitude, proved that the order of succession in the lines over the plains and on the Juras and other distant heights, corresponded with the geographical positions of the peaks. He thus determined the height of the Alpine sources and the limits of the drift over a region 300 miles long and 200 wide, and demonstrated the morainic character of the erratic material, and the identity between the laws of existing glaciers and those of the former great ice-mass that had covered all Switzerland. The specimens collected from all the lines of stones to the mountain tops are now arranged geographically in the Princeton Museum, which contains also the other gifts from him, its Curator, and evidence of his care everywhere, and which has recently been named the Guyot Museum.

The "*Système Glaciaire*," published in 1847, has for its full title, "Système Glaciaire, ou Recherches sur les Glaciers, leur mécanisme, leur ancienne extension, et le rôle qu'ils ont joué dans l'Histoire de la Terre, par MM. L. Agassiz, A. Guyot and E. Desor; Premiere Partie." This *first* part was the great work of Agassiz on glaciers. But although so valuable, it was unfortunate for science that the other parts failed of publication, owing to revolutionary movements in Switzerland which were destructive to the Neuchâtel University. Guyot's views appeared in brief in the Bulletin of the Neuchâtel Society of Natural Sciences, and are cited in the second volume of d'Archiac's "Histoire des progrès de la Géologie" (1848).

In 1848 Guyot came to this country, following the course of Agassiz who reached America two years before. Switzerland lost much in this removal of two of her ablest professors, but America gained vastly more. While Agassiz infused new ideas into the people and the schools and other educational institutions of the land as to the value of natural science and the methods of instruction, Guyot gave, with like effect, new methods and widened comprehension with regard to the relations of physical

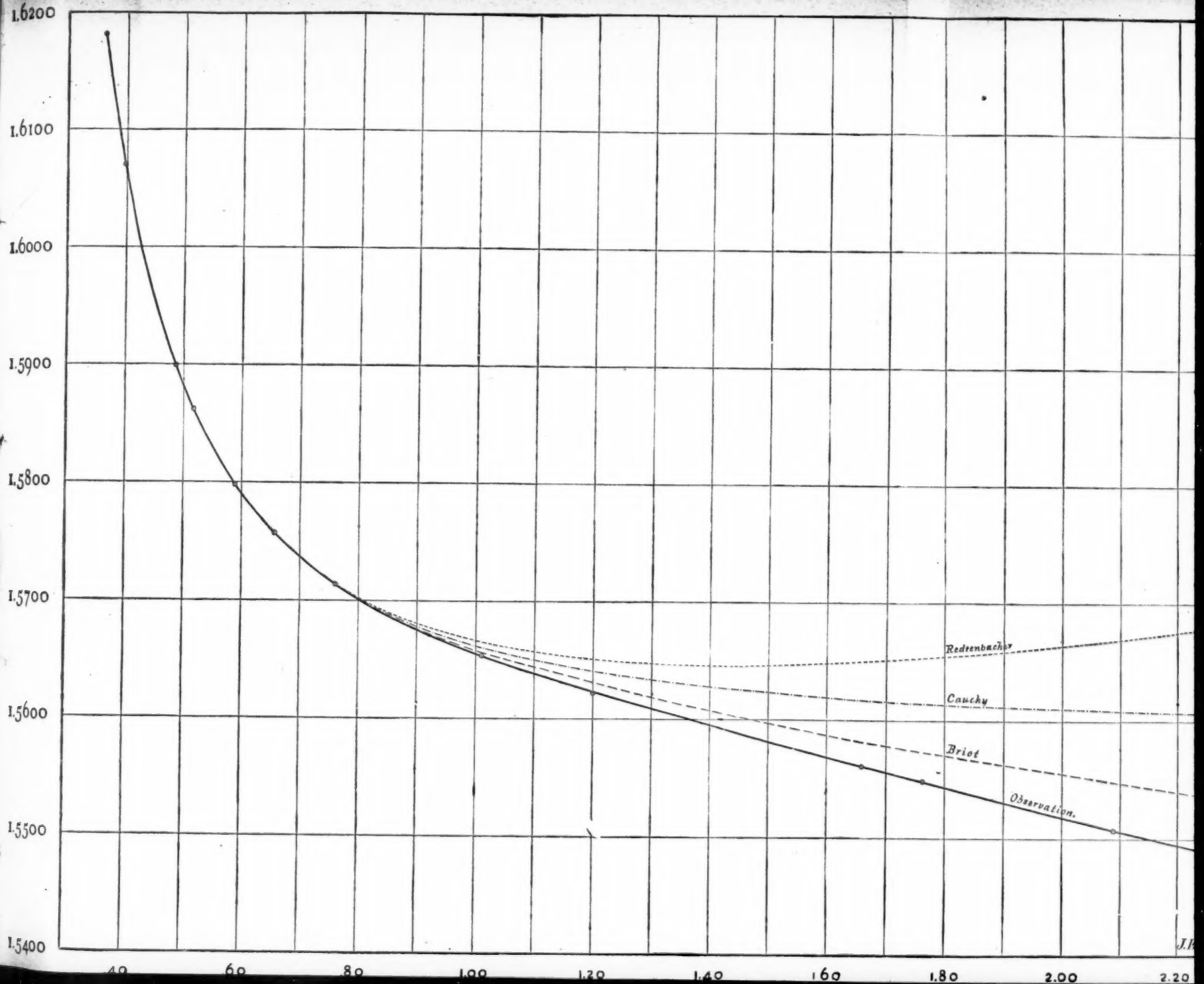
geography to man and history, and to the true objects of geograpical study. For six years Guyot was employed by the Massachusetts Board of Education as lecturer to the normal schools of the State on geography and the best ways of teaching it. The year after his arrival in the country he delivered in French a course of lectures in Boston, which were afterward translated by Professor Felton, of Harvard, and published under the title of "Earth and Man." The volume exhibits the broad philosophic views and exalted tone of mind and heart of its author, and commenced his period of influence over geographical education among us.

In 1850 he organized the system of meteorological observations put into action by the Smithsonian Institution, and advised as to the construction of instruments for the purpose. In 1851 to 1859 he prepared a volume of *Meteorological and Physical tables*, published by this Institution. He began at the same time a systematic study of the physical geography of the United States, especially as regards the features of its mountains and the heights of their peaks, from northern New England to South Carolina. The principal results up to 1861 are presented in one of the volumes of this Journal for that year, in a paper "on the Physical Structure of the Appalachian System." His last work of this character was carried on in the Catskill Mountains, during several summers between 1862 and 1879, the latter two years after he had passed his 70th birthday. It was a work of great difficulty on account of the pathless forests spreading over many of the summits, which were mostly featureless, and the necessity in some cases of climbing to the tops of the highest trees to gain a view of the neighboring summits for triangulation. He carried his survey through with wonderful precision, considering the difficulties, discovered heights among the peaks greater than had before been known, and has given an excellent map of the region. (This Journal, volume xix, 1880.)

Professor Guyot's theological and scientific training fitted him to make a judicious exposition of the first chapter of Genesis. A brief statement of his views on the subject has been before the country in the chapter on Cosmogony in Dana's Manual of Geology, derived orally from him. The closing labor of his life was the preparation of a volume of 200 pages on this subject, and the last proofs had been read just before his death.* Professor Guyot believed in the spiritual not less than in the material; in Nature's laws, and in the Infinite Lawgiver, the Author of Nature; and his life was throughout a manifestation of his Christian faith.

Professor Guyot received his professorship at Princeton, in 1855. He was one of the original members of the National Academy of Sciences. His excellent wife, who survives him, was the daughter of ex-Governor Haines, of New Jersey. J. D. D.

* Published by Scribner's Sons, New York, the publishers of his school geographies, atlases, and maps.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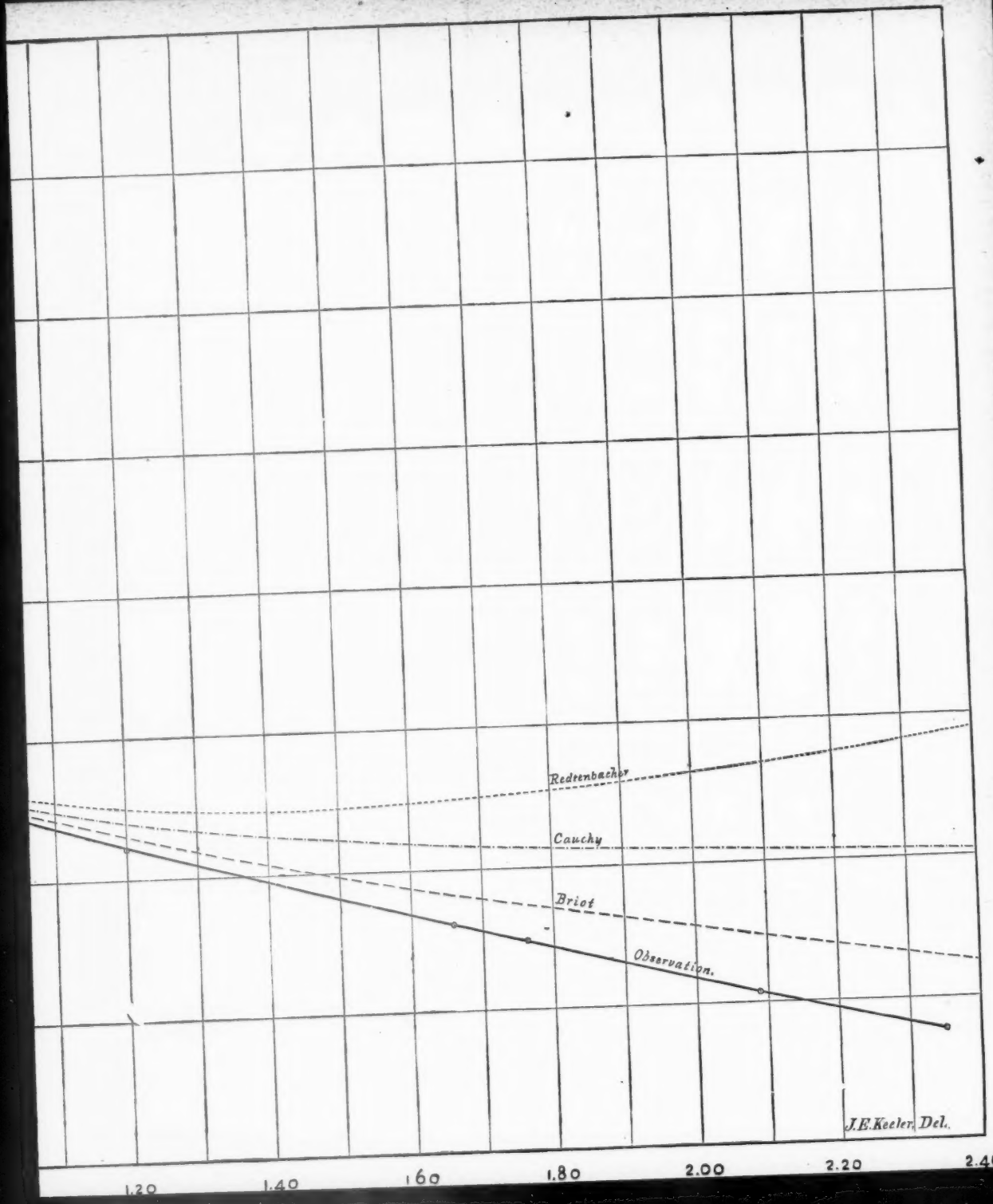
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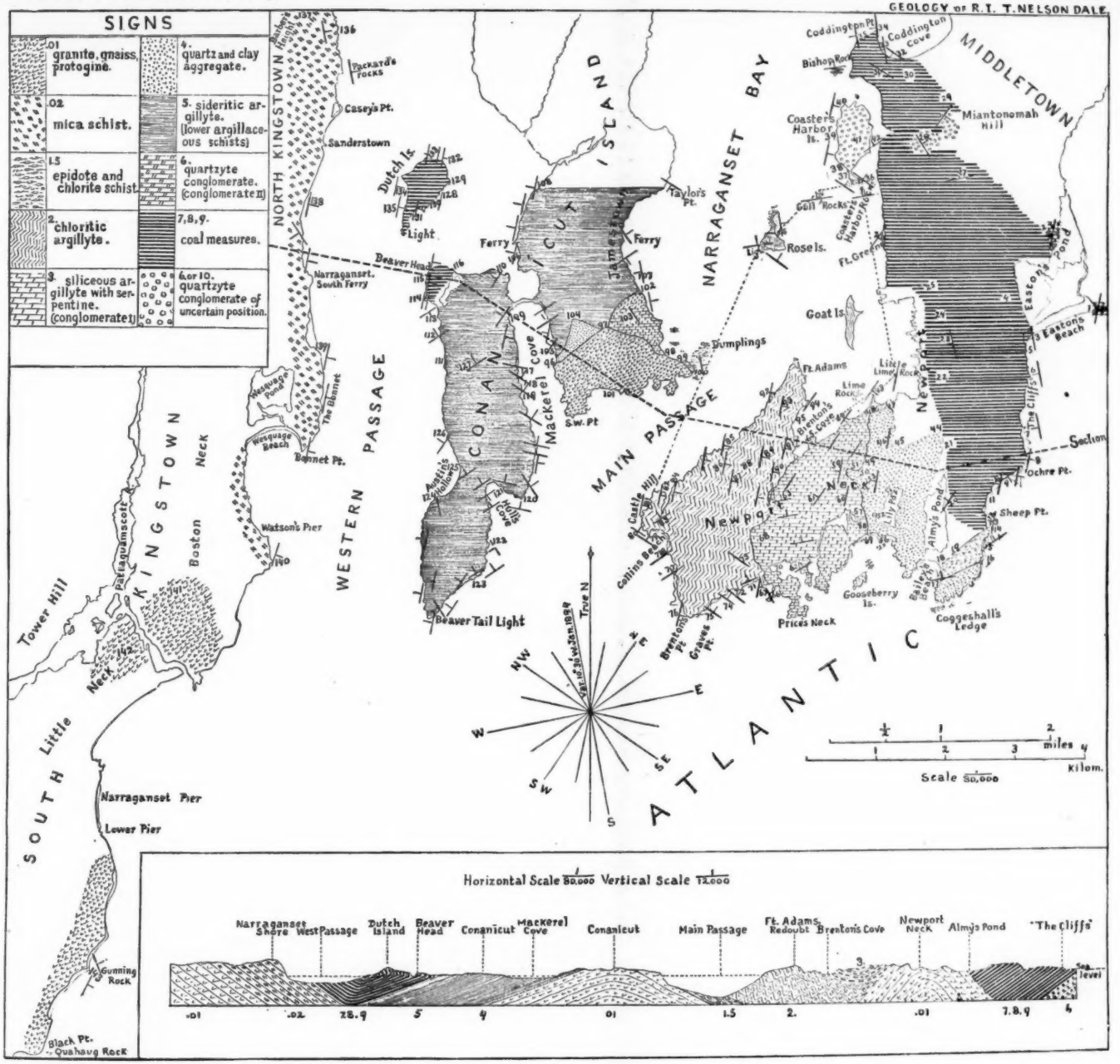
GEOLOGY OF R.I. T. NELSON DALE
SIGNS
.01 granite, gneiss, protogine.
.02 mica schist.
1.5 epidote and chlorite schist
2. chloritic argillyte.
3. siliceous argillyte with serpentine. (conglomerate I)
4. quartz and clay aggregate.
5. sideritic argillyte. (lower argillaceous schists)
6. quartzyte conglomerate. (conglomerate II)
7,8,9. coal measures.
4 or 10. quartzyte conglomerate of uncertain position.
NORTH KINGSTOWN
CONANICUT ISLAND
NARRAGANSET BAY
MIDDLETOWN
WESTERN PASSAGE
MAIN PASSAGE
ATLANTIC
SOUTH KINGSTOWN
Little Neck
Boston Neck
Tower Hill
Narragansett Pier
Lower Pier
Gunning Rock
Black Pt.
Quahaug Rock
Sanderstown
Packard's Rocks
Casey's Pt.
Dutch Is.
Light
Beaver Head
Narragansett South Ferry
Wesquage Pond
Wesquage Beach
Bonnet Pt.
The Bonnet
Watson's Pier
Beaver Tail Light
Austin's Hollow
Mackerel Cove
Conanicut
Ferry
Jamestown
Taylor's Pt.
Dumplings
S.W. Pt.
Coddington Pt.
Coddington Cove
Bishop Rock
Coaster's Harbor Is.
Miantonomah Hill
Gull Rocks
Rose Is.
Coaster's Harbor
Fl. Green
Goat Is.
Easton's Pond
Easton's Beach
The Cliffs
Ochre Pt.
Sheep Pt.
Ft. Adams
Little Lime Rock
Lime Rock
Brenton's Cove
Castle Hill
Newport
Neck
Almy's Pond
Collins Beach
Gooseberry Is.
Prices Neck
Bailey's Beach
Coggeshall's Ledge
Brenton Pt.
Graves Pt.
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Scale 50,000
Horizontal Scale 1/80,000 Vertical Scale 1/12,000
Narragansett Shore
West Passage
Dutch Island
Beaver Head
Conanicut
Mackerel Cove
Conanicut
Main Passage
Ft. Adams Redoubt
Brenton's Cove
Newport Neck
Almy's Pond
"The Cliffs"
Sea level
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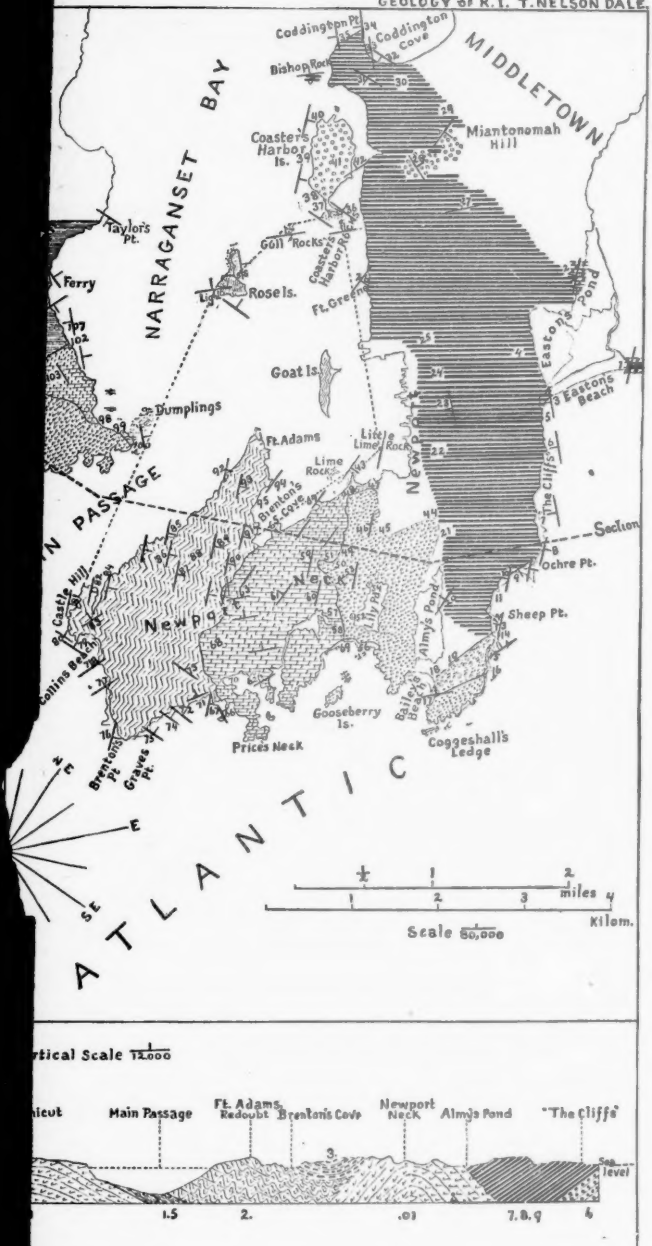
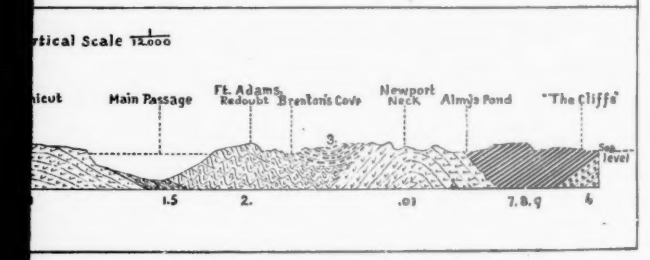
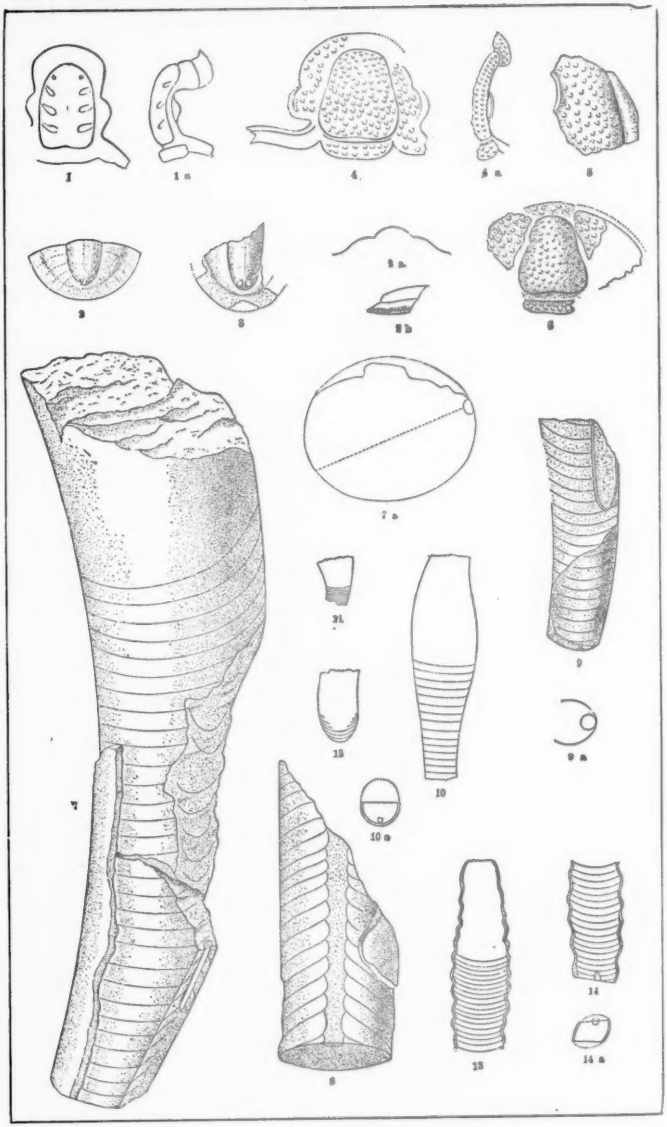
Plate VI.

GEOLOGY of R.I. T. NELSON DALE.